SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

Special Features

1952 Literature Review—Research Committee

Phosphorus Removal—Owen

Packinghouse Waste Digestion—Fullen

Spray Irrigation—Dennis

MAY, 1953—VOL. 25, No. 5

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TWENTY-SIXTH ANNUAL MEETING

OF THE

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

IN CONJUNCTION WITH

FLORIDA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

BAYFRONT AUDITORIUM

MIAMI, FLORIDA

October 13-16, 1953

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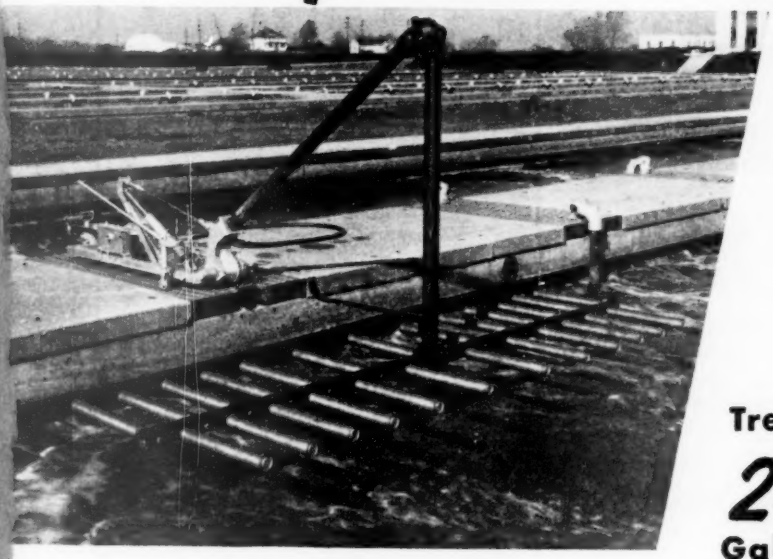

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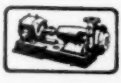

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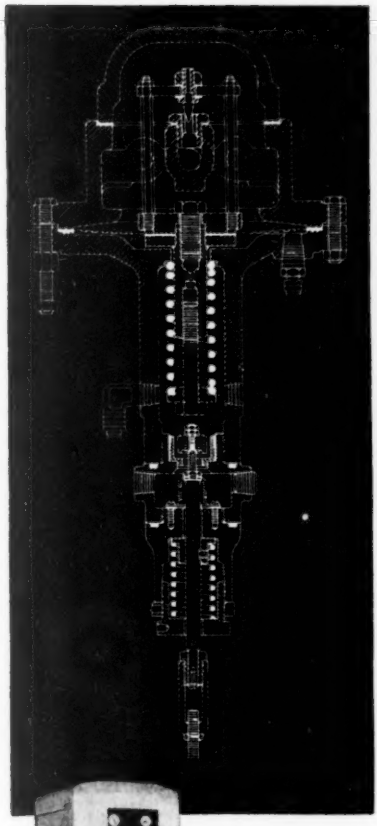

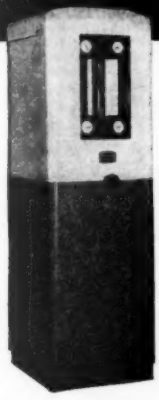

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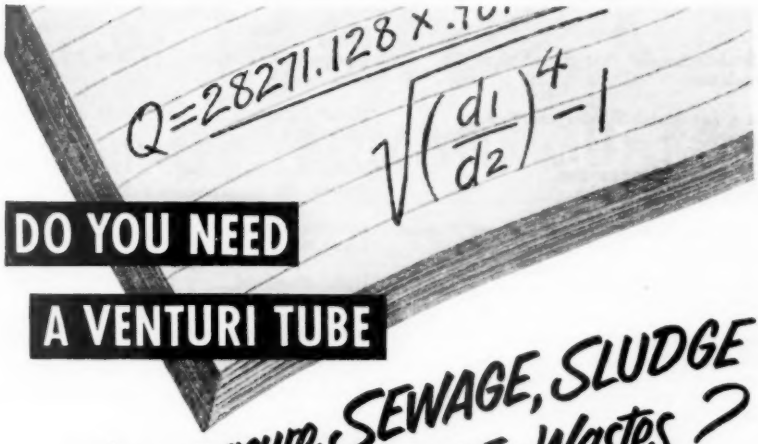

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Association	*Place*	*Time*
Maryland-Delaware Water and Sewerage Association	Commander Hotel, Ocean City, Md.	May 20–21, 1953
Virginia Industrial Wastes and Sewage Works Association	Hotel Jefferson, Richmond, Va.	May 21–22, 1953
Central States Sewage and Industrial Wastes Assn.	Hotel Pere Marquette, Peoria, Ill.	June 3–5, 1953
New England Sewage and Industrial Wastes Association	Laconia Tavern, Laconia, N. H.	June 4–5, 1953
New York Sewage and Ind. Wastes Association	Hotel Sheraton, Rochester, N. Y.	June 8–9, 1953
Alabama Water and Sewage Association	Univ. of Alabama, University, Ala.	June 8–12, 1953
Ohio Sewage and Industrial Wastes Treatment Conference	Mayflower Hotel, Akron, Ohio	June 17–19, 1953
Pennsylvania Sewage and Industrial Wastes Assn.	Pa. State College, State College, Pa.	Aug. 26–28, 1953
West Virginia Sewage and Industrial Wastes Association	Hotel Morgan, Morgantown, W. Va.	Sept. 2–3, 1953
Iowa Sewage Works Assn.	Iowa State College, Ames, Iowa	Sept. 2–4, 1953
Rocky Mountain Sewage Works Association	Hotel La Fonda, Santa Fe, N. M.	Sept. 21, 1953
Kentucky-Tennessee Industrial Wastes and Sewage Works Assn.	Owensboro Hotel, Owensboro, Ky.	Sept. 21–23, 1953
Missouri Water and Sewerage Conference	Elms Hotel, Excelsior Springs, Mo.	Sept. 27–29, 1953

TWENTY-SIXTH ANNUAL MEETING

Federation of Sewage and Industrial Wastes Associations
in conjunction with
Florida Sewage and Industrial Wastes Association
Municipal (Bayfront Park) Auditorium, Miami, Florida
October 13–16, 1953

Address hotel reservation requests to: FSIWA Convention Housing Bureau, 320 N.E. Fifth Street, Miami, Florida

New England Sewage and Industrial Wastes Association	Wannamoisett Country Club, 96 Hoyt Avenue, East Providence, R. I.	Nov. 5, 1953
North Carolina Sewage and Industrial Waste Association	Sheraton Hotel, High Point, N. C.	Nov. 9–11, 1953
Nebraska Sewage and Industrial Wastes Association	Hotel Capital, Lincoln, Nebr.	Nov. 12–13, 1953
Oklahoma Water, Sewage and Industrial Waste Conference	Okla. A & M College, Stillwater, Okla.	Nov. 16–20, 1953

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The *Yeomans Guard*, published several times a year, is a compendium of news and useful information covering the pumping of materials and the treatment of wastes, both domestic and industrial. We shall be pleased to send you the current issue if you'd care to have it. Ask your local Yeomans Representative—listed in the telephone book yellow pages under "Pumps"—or write direct.

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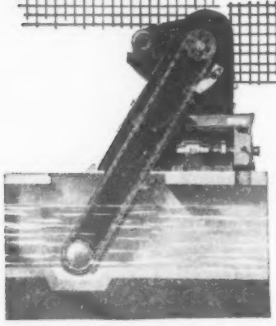

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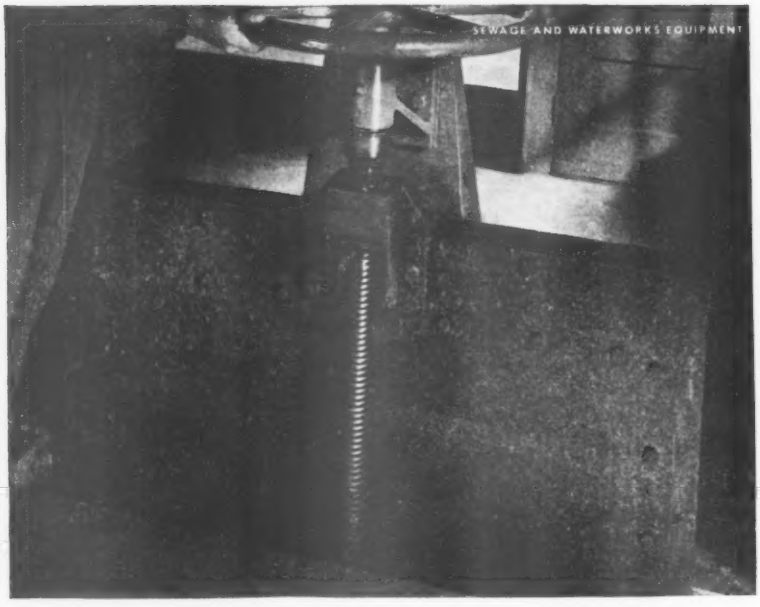

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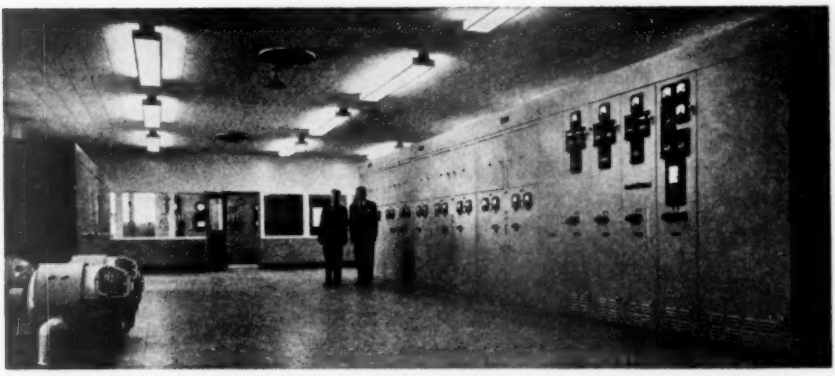
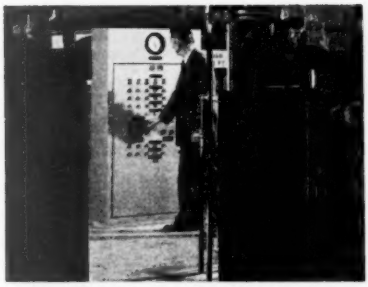
CORROSION-RESISTANT



Typical of modern G-E equipment is this switchgear and Limitamp control lineup at a new west coast plant.

3-way aid for your Clean Waters plan



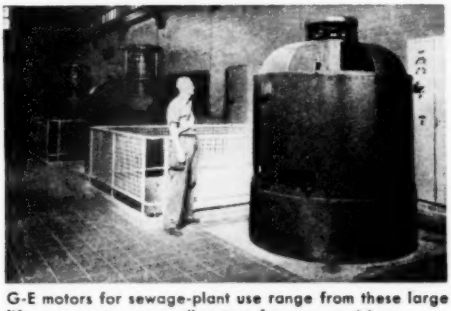
Special control like this chlorinator panel is part of complete G-E equipment for sewage plants.

Available now to all communities faced with the need for new or expanded sewage-treatment facilities is this three-way help from General Electric:

1. **Community-action program,** including the film *Clean Waters* to aid you in increasing public support for necessary new projects.
2. **Engineering assistance** to your consultants or engineers in electrical-system planning.
3. **Co-ordinated electrical equipment** supplied from the complete G-E line of motors, control and power distribution equipment.

To take advantage of this complete service, contact your nearest G-E Apparatus Sales Office early in the planning of your project. General Electric Co., Schenectady 5, N. Y. 666-75

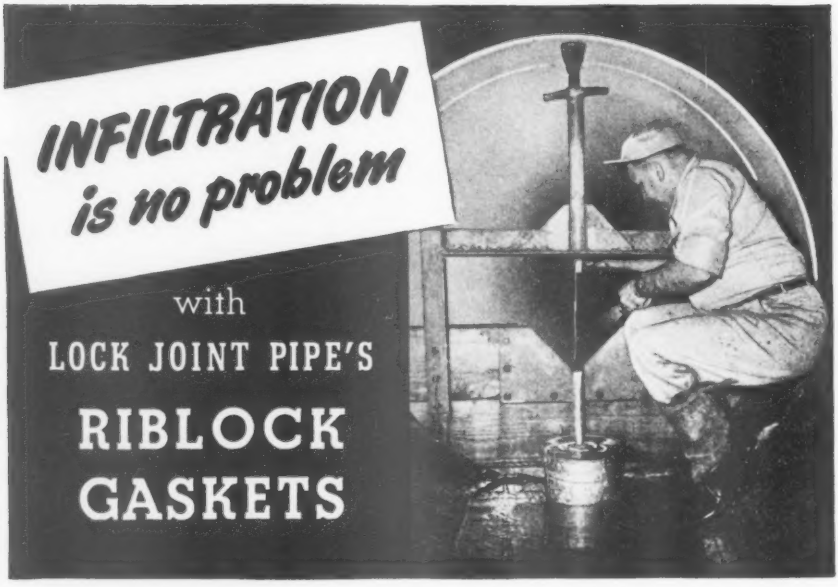
Clean Waters program consists of film, manual *Modern Sewage Treatment,* handout leaflets.



G-E motors for sewage-plant use range from these large lift-pump motors to small motors for process drives.

Engineered Electrical Systems for Sewage Plants

GENERAL ELECTRIC



Actual field tests made on pipe laid under severe ground water conditions prove that the problem of infiltration can be overcome by using Lock Joint Reinforced Concrete Sewer Pipe equipped with Riblock Gaskets.

Bogert-Childs Associates, consulting engineers for the enormous Overpeck Sewer Project, conducted a detailed weir test on approximately 7,000 feet of 60" Lock Joint Reinforced Concrete Sewer Pipe with Riblock joints which were installed across the North Jersey swamps and marshlands. This test, which showed only 15 per cent of the volume of infiltration permitted in the specifications, pointed conclusively to the value of Lock Joint sewer pipe and Riblock gaskets for installations of this difficult nature.

For nearly 50 years Lock Joint Pipe Company has been furnishing the most durable and dependable sewer, storm drain, and culvert pipe obtainable. Now, by including Riblock Gaskets in the specifications, you can also assure joints with permanently reliable protection against ground water infiltration.

• • • • •

LOCK JOINT PIPE COMPANY

Established 1905

P. O. Box 269, East Orange, New Jersey

BRANCH OFFICES: Casper, Wyo. • Cheyenne, Wyo. Denver, Col. • Kansas City, Mo. • Valley Park, Mo. Chicago, Ill. • Rock Island, Ill. • Wichita, Kan. Kenilworth, N. J. • Hartford, Conn. • Tucumcari, N. M. Oklahoma City, Okla. • Tulsa, Okla. • Beloit, Wis.

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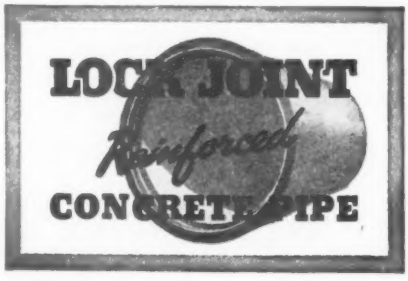


This "whirling tube" is inside the amazing Fairbanks-Morse *Bladeless* Impeller Pump . . . just a "whoosh" and fibrous material goes right through.

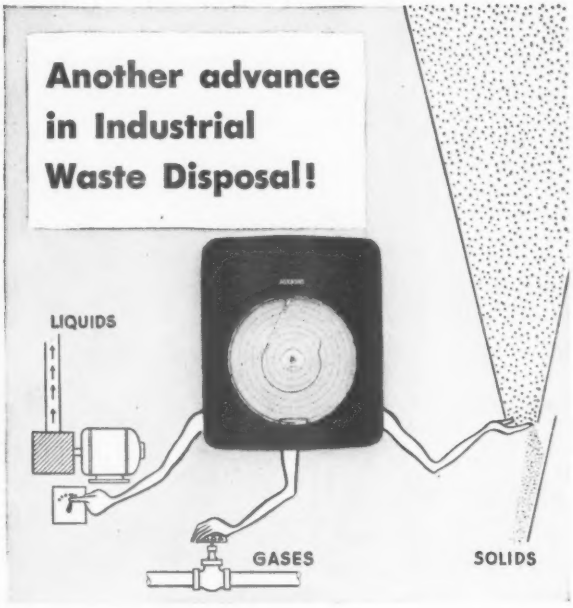
Fairbanks-Morse engineers designed this impeller without blades or projections that catch and hold trash—it's truly non-clog. Even a man's complete coveralls went through a 4-inch pump without clogging!

See your Fairbanks-Morse Distributor or Local Branch Office about this *Bladeless Impeller* Pump . . . or write Fairbanks, Morse & Co., Chicago 5, Illinois.

FAIRBANKS-MORSE

a name worth remembering when you want the best

PUMPS • SCALES • DIESEL LOCOMOTIVES AND ENGINES • ELECTRICAL MACHINERY
RAIL CARS • HOME WATER SERVICE EQUIPMENT • FARM MACHINERY • MAGNETOS



AUTOMATIC CONTROL for Proportioning of Treating Chemicals

Feeding of treating chemicals at rates proportionate to flow can *now be done automatically* — with total elimination of time-consuming, periodic adjustment of feeders and pumps. In addition, the proportioning of chemicals is far more accurate, which means a more uniform, satisfactory effluent and a definite saving in cost of chemicals.

The instrument control system is properly engineered for individual plant conditions. Its design depends upon the quantity, corrosive quality, and viscosity of the activated silica, carbon dioxide, soda ash, lime, or other chemicals employed . . . also upon the amount of chemicals to be stored and the type of plant operation.

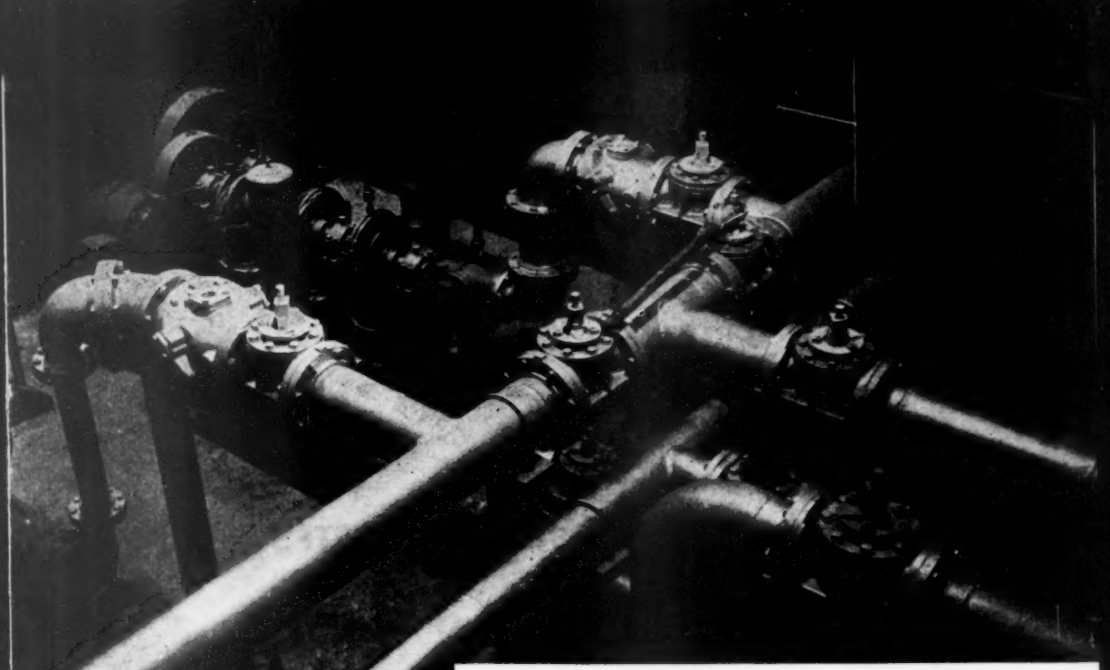
Virtually *any* set of conditions can be met with one or another of the following instrument control methods offered by Foxboro:

1. *ratio flow control with pneumatic control valves for liquid chemicals or gases.*
2. *control of motor operation on dry feeders or on proportioning pumps by "pulse-time" control.*
3. *motor speed control on dry feeders or proportioning pumps through electronic control of power input.*

One of these methods may bring substantial new economies to the operation of your waste disposal system. For engineering recommendations, write us the details of your problem. **The Foxboro Company, 885 Neponset Ave., Foxboro, Mass.**

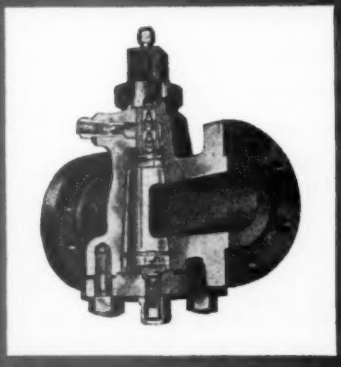
FOXBORO REG. U. S. PAT. OFF. *Instrumentation*

INDICATING • RECORDING • CONTROLLING



Nordstrom Lubricant-Sealed valves installed on sludge lines at a South Carolina sewage treatment plant.

THE NORDSTROM PRINCIPLE OF INTERNAL LUBRICATION



The body and plug of a Nordstrom valve are so constructed that lubricant-filled grooves surround seat port when the valve is in an open or closed position. This lubricant forms an impenetrable seal preventing flow of line fluid between plug and body. In addition to the lubricant-filled grooves, a thin film of lubricant completely covers contact surfaces of plug and body allowing the plug to slide easily within the body without abrasive friction.

When necessary, the film of lubricant covering contact surfaces and the supply of lubricant in the grooves can be instantly replenished by a simple turn of the lubricant screw.

DO SEWAGE TREATMENT SERVICES NEED A *Lubricated* VALVE?

Occasionally you'll find someone who thinks that because pressures and temperatures are not so high in sewage treatment plants as in other industries, a non-lubricated valve can do the job as well as a Nordstrom. Is this so? Definitely not!

A Nordstrom Lubricant-Sealed valve on *any* type of sewage treatment service has many advantages that can't be duplicated by a non-lubricated valve. Here are a few:

1. In a Nordstrom, the seating area is *never exposed* to line fluid, so corrosive and abrasive services can't wear away the vital seating contact.
2. Seat ports are completely surrounded by lubricant-filled grooves. Lubricant acts as a seal *preventing leakage* whether the valve is opened or closed.
3. A Nordstrom *lasts longer* than non-lubricated valves, because any mechanism of moving metal parts needs lubrication to prevent friction.
4. A Nordstrom is always ready to operate with a quick quarter-turn. The plug glides on a film of lubricant permitting *effortless, instant operation.*

These advantages—seat never exposed; lubricant-sealed shut-off; longer valve life; easy, instant operation—mean that Nordstrom Lubricant-Sealed valves can be depended upon to give efficient, trouble-free performance year after year on any sewage treatment service. Rockwell Manufacturing Company, Pittsburgh 8, Pennsylvania.

ROCKWELL Built Nordstrom Valves

Lubricant-Sealed for Positive Shut-Off

Another Rockwell Product

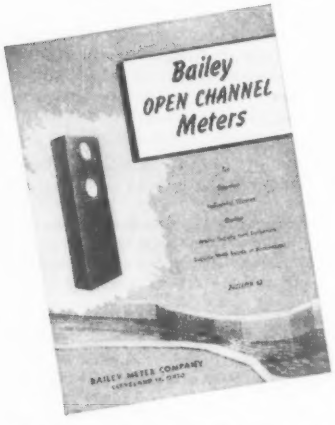
For trouble-free, low cost measurement of—

SEWAGE
INDUSTRIAL WASTES
SLUDGE
IRRIGATION WATER

BAILEY

OPEN CHANNEL METERS

Offer These Advantages:



1. Easy to Install
2. Retain Accuracy
3. Self-Cleaning
4. Adjustable Capacities
5. Totalize Multiple Flows
6. Chemical Feed Control
7. Flow and Ratio Controls

Ask for Bulletin 62

MU22

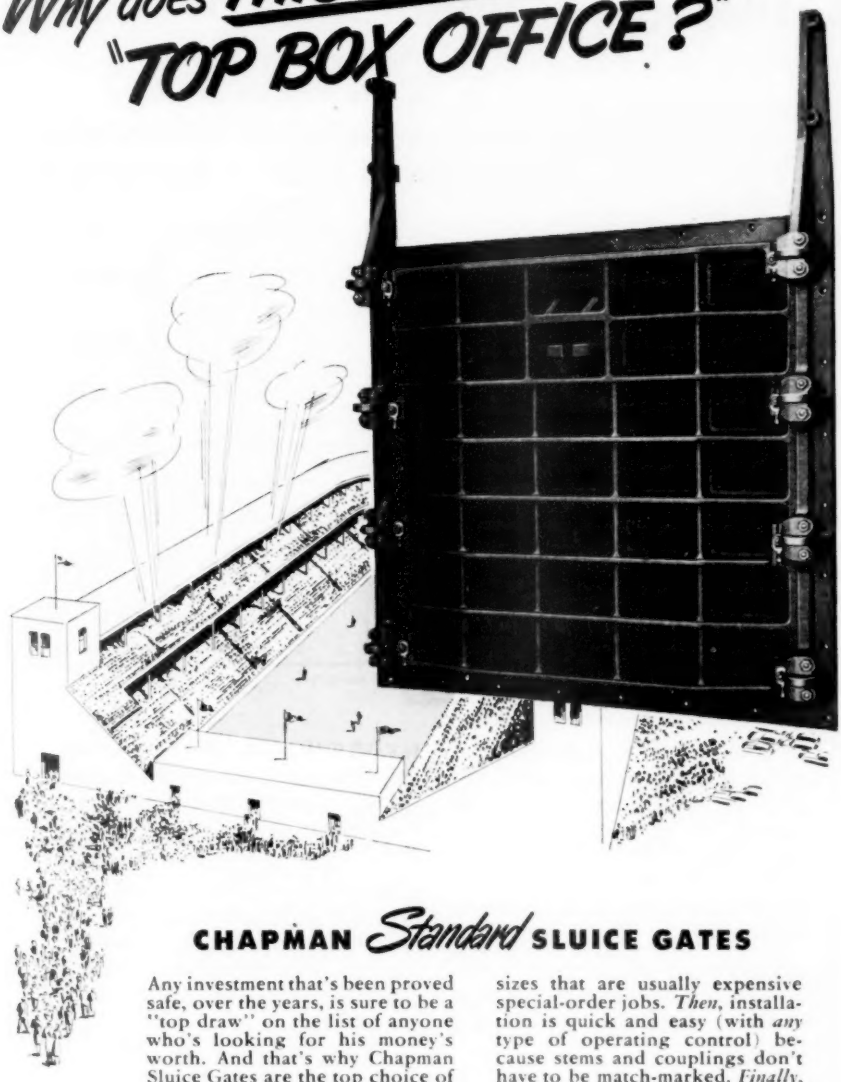
BAILEY METER COMPANY

1066 IVANHOE ROAD • CLEVELAND 10, OHIO

METERS and CONTROLS for SEWAGE and WATER

VENTURI TUBES, FLUMES, WEIRS, NOZZLES, ORIFICES • DIRECT MECHANICAL AND REMOTELY LOCATED REGISTERS • AIR-OPERATED, ELECTRONIC AND ELECTRIC CONTROLS.

Why does THIS GATE always draw "TOP BOX OFFICE?"



CHAPMAN *Standard* SLUICE GATES

Any investment that's been proved safe, over the years, is sure to be a "top draw" on the list of anyone who's looking for his money's worth. And that's why Chapman Sluice Gates are the top choice of shrewdly managed waterworks, sewage works and flood control projects all over the country.

There are 3 good reasons for this: *First*, Chapman's Standard Line includes many types and sizes that are usually expensive special-order jobs. *Then*, installation is quick and easy (with *any* type of operating control) because stems and couplings don't have to be match-marked. *Finally*, any servicing needed can be done on the job, without alterations. See what Chapman Standard Sluice Gates can save for your project. Write for catalog No. 25.

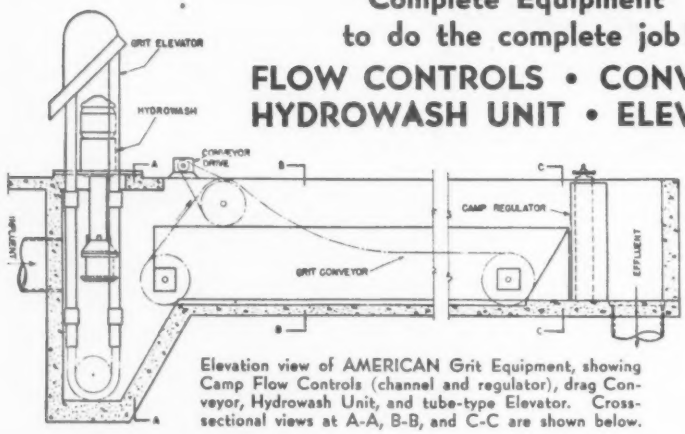
The Chapman Valve Mfg. Co., Indian Orchard, Mass.

REMOVE GRIT

EASILY...THOROUGHLY...AT LOW COST!

Complete Equipment to do the complete job!

FLOW CONTROLS • CONVEYOR
HYDROWASH UNIT • ELEVATOR



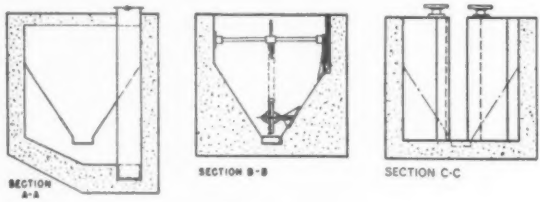
Elevation view of AMERICAN Grit Equipment, showing Camp Flow Controls (channel and regulator), drag Conveyor, Hydrowash Unit, and tube-type Elevator. Cross-sectional views at A-A, B-B, and C-C are shown below.

PROVIDES CONSTANT OPTIMUM VELOCITY

POSITIVE ADJUSTMENT FOR VARYING FLOWS

HYDRO-DYNAMIC WASHING

AUTOMATIC DRAINING AND REMOVAL



FLOW CONTROLS—exclusive Camp Control Section and Regulator maintain constant optimum velocity for effective grit settling, regardless of rate of flow through plant. Velocity can be easily and instantly adjusted to meet changing conditions.

CONVEYOR—single strand, continuous drag type carries grit from channel to hopper for washing and removal.

HYDROWASH UNIT—washes grit free of organic matter by producing a turbulent downflow recirculation of liquor in grit hopper.

ELEVATOR—totally enclosed, tube type, for slow and continuous removal of washed grit from the hopper. Grit drains as it is being elevated through the tube.

Write for Bulletin No. 249A

Technical Supplement "CR", containing complete design data on the AMERICAN CAMP GRIT CHANNEL and REGULATOR is available on request with Bulletin 249A.

AMERICAN WELL WORKS

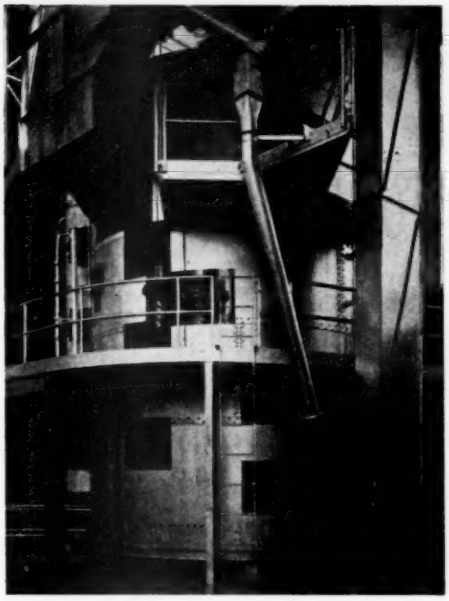
IN OUR 85TH YEAR
110 North Broadway
AURORA, ILLINOIS

Pumping, Sewage Treatment, and Water Purification Equipment
RESEARCH · ENGINEERING · MANUFACTURING

Offices: Chicago • New York • Cleveland • Cincinnati • Kansas City • Sales Representatives throughout the World

Nichols Design-Experience Make the *big* difference

- **Less treatment time**
- **One unit for drying and/or incinerating**
- **Compact, space-saving plant**



Nichols Multiple Hearth Dryer-Incinerator.

Nichols Multiple Hearth Dryer-Incinerator design gives the municipality extra dollar value because it reduces treatment time, incinerates raw or digested sludge with equal facility . . . because one unit can be used to dry sludge or to burn it to a sterile ash . . . because plant layout is compact, excluding unsightly drying beds, lagoons, etc.

We welcome inquiries from interested municipalities.

NICHOLS Engineering & Research Corp.
70 PINE ST., NEW YORK 5, N. Y.
1920 N. Meridian St., Indianapolis 2, Ind.
40 S. Los Robles Ave., Pasadena 1, Calif.
1477 Sherbrooke St. W., Montreal 25, Canada

SEWER DESIGNS ARE NO GOOD... on paper!

The best of sewer designs are of little value until they are incorporated into a functioning conduit. Even then the conduit must have adequate strength and material durability to maintain your design specifications throughout its normal life. This is why many experienced engineers are specifying Armco Corrugated Metal Sewers.

Consider the importance of structural strength. The efficiency of any sewer will change unless it retains grade and alignment, has tight joints to prevent infiltration of ground water and solids, as well as material strength to withstand the impact and vibration of heavy traffic.

Armco Sewers meet these requirements. Long lengths help bridge soft spots in the foundation. Sturdy coupling bands assure tight joints and a continuous conduit of uniform strength that will not open up or pull apart. The proved strength of flexible corrugated metal design is assurance against crushing or cracking.

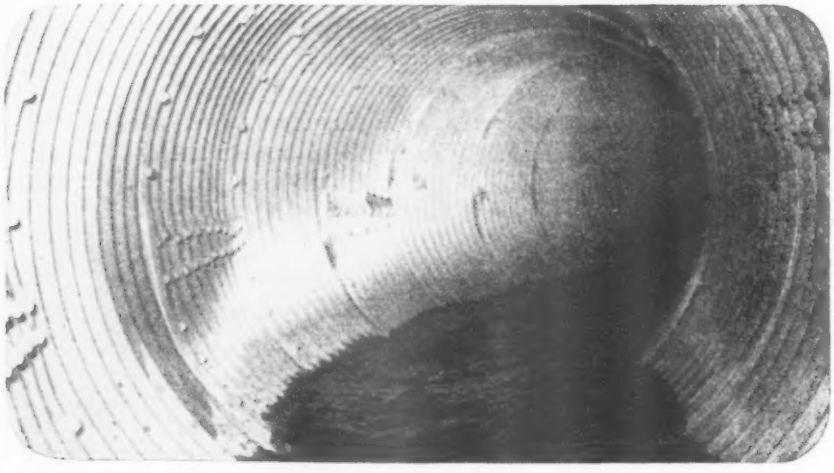
And no matter what service conditions are encountered there is a type of Armco structure to meet the exact requirements. Erosion is handled by Armco PAVED-INVERT Pipe. For severe corrosive conditions there is durable ASBESTOS-BONDED. Easily erected MULTI-PLATE is ideal for large structures and either Standard Corrugated or MULTI-PLATE Pipe-Arch will save time and money when headroom is limited.

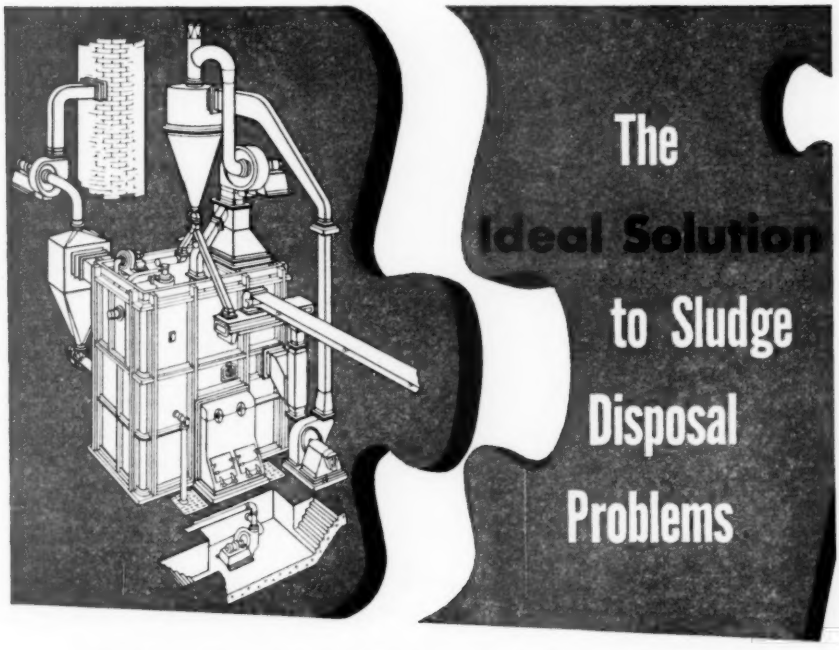
Write for complete information regarding your specific needs. Armco Drainage & Metal Products, Inc., 1043 Curtis Street, Middletown, Ohio. Subsidiary of Armco Steel Corporation.

ARMCO SEWER STRUCTURES

ARMCO

This Armco Sanitary Sewer was installed by a midwestern city in 1930. More than twenty years later it retains its original efficiency and has many more years of useful life expectancy.





Here is the modern method of sludge disposal – the C-E Raymond System of Flash Drying and Incineration. Continuously, automatically, this system incinerates thickened sludge to a fine ash, free from clinker and unburned materials . . . or flash dries it to fertilizer, containing all of the original fertilizer constituents.

C-E systems now in service are meeting the requirements of both large and small communities – serving equivalent populations from 14,000 to 3,600,000. The list below shows the most recent installations.

C-E Raymond Systems are flexible in layout, highly efficient and fully reliable; they provide for maximum utilization of waste heat. They mean for any community the end of stream or atmospheric pollution resulting from the disposal of sewage wastes.

The services of C-E specialists are available to help you plan for the most practical and economical answer to your sludge disposal problems. For prompt attention, get in touch with one of the Combustion offices listed below. B-669A

C-E Raymond Systems installed, under construction or on order since 1945

Installation	Consulting Engineer
Baltimore, Md.	Whitman, Requardt & Associates
Bethlehem, Pa.	Morris Knowles
Bloomsburg, Pa.	Gannet, Fleming, Corddry & Carpenter
Camden, N. J.	Havens & Emerson
Chicago, Ill. (W. Southwest)	City Engineering Dept.
Edgewater, N. J.	McClave & McClave
Fond du Lac, Wis.	Jerry Donohue Engrg. Co.
Houston, Texas	Greeley and Hansen
Lansing, Mich.	Drury, McNamee and Porter
Los Angeles, Cal.	Metcalf and Eddy
San Diego, Cal.	Frank Currie
San Francisco, Cal.	Clyde C. Kennedy
Schenectady, N. Y.	Havens and Emerson
Sheboygan, Wis.	Jerry Donohue Engrg. Co.
Washington, D. C.	Greeley and Hansen
Waterbury, Conn.	Malcolm Pirnie
Wyomissing Valley, Pa.	Albright & Friel
York, Pa.	Albright & Friel

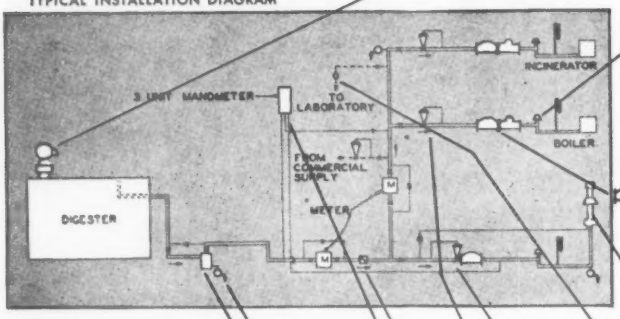
COMBUSTION ENGINEERING, INC.

FLASH DRYER DIVISION
1315 North Branch Street
Chicago 22, Illinois

Western Office: 510 W. Sixth, Los Angeles 14, Cal.
Eastern Office: 200 Madison Ave., N. Y. 16, N. Y.

ALSO FLASH DRYING AND INCINERATION SYSTEMS FOR INDUSTRIAL WASTE DISPOSAL

TYPICAL INSTALLATION DIAGRAM



"VAREC" Pressure Relief and Vacuum Breaker Valve with Flame Arrester — Fig. 5800C — Relieves excess pressures and vacuum in digesters and protects vessels from outside fires.

"VAREC" Explosion Relief Valve—Fig. 70—Relieves sudden surges in pressure from explosion or momentary plant fluctuations.

"VAREC" Flame Trap Assembly—Fig. 450—Prevents flame propagation in piping.

"VAREC" Waste Gas Burner—Fig. 236, 237 or 238—Efficiently burns all excess gas.

"VAREC" Flame Check—Fig. 51A or 52A—Prevents flashback from burner pilot or laboratory burners.

"VAREC" Pressure Relief and Flame Trap Assembly—Fig. 440—Permits excess pressure to be wasted through gas burner and prevents flame flashback from burner.

"VAREC" Pressure Reducing Regulator—Fig. 187 or 387—Controls pressure of gas going to utilization equipment.

"VAREC" Check Valve—Fig. 211 or 211A—Controls direction of gas flow.

"VAREC" Manometer—Fig. 215, 215A, 216 or 216A—Indicates system pressures.

"VAREC" Drip Trap—Fig. 245 or 248.

"VAREC" Sediment Trap — Fig. 230, 232 or 233 — Keeps lines drained and free from moisture.

Plan with "Varec" Symbols of Safety

FOR GAS CONTROL THROUGHOUT YOUR SEWAGE TREATMENT PLANT

PROVED and APPROVED "Varec"

THE VAPOR RECOVERY SYSTEMS COMPANY

COMPTON, CALIFORNIA, U. S. A.

S-10 *Available from Authorized Sewage Equipment Agents throughout U. S. and Canada.*

Sludge Collectors
Sludge Elevators
Grit Washers
Grit Collectors
Scum Removers
Spiral Conveyors
Screenings Grinders
Garbage Grinders
FLOCTROLS
Rapid Mixers
Bucket Elevators
Chains, Sprockets, Bearings

They do things up in a big way down in Texas, and Dallas is no exception. When it came to specifying the most modern equipment for treating sewage, Jeffrey received the call.

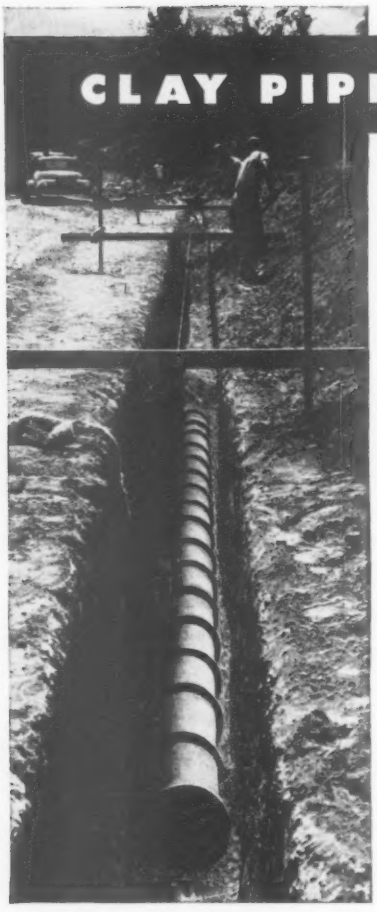
Screens, Grinders, and Grit Collectors . . . combined into a coordinated system to provide an efficient plant for this large and progressive city in the southwest.

We could name you hundreds of cities, as big as and often larger than Dallas, in which Jeffrey sewage and water treatment equipment is performing in a most satisfactory manner. Specify Jeffrey if you want the best . . . the most modern.

Catalog No. 833

THE JEFFREY MANUFACTURING CO.
Columbus 16, Ohio
sales offices and distributors in principal cities
PLANTS IN CANADA, ENGLAND, SOUTH AFRICA

IF IT'S MINED, PROCESSED OR MOVED
. . . IT'S A JOB FOR JEFFREY!



CLAY PIPE *Specified*

For New Tuscaloosa Municipal Sewer Project

More than 44,000 feet of Vitrified Clay Pipe are being installed to serve a growing residential area in Tuscaloosa, home of the University of Alabama.

Because Clay Pipe proved outstanding over the years in Tuscaloosa sewerage installations, it was again first choice for the current $170,000 sewer expansion program. City engineers throughout the country rely on the dependability and proven performance of Vitrified Clay Pipe for sanitary sewers. It's guaranteed for 50 years!

Clay Pipe is readily available, too. It's *all* clay — an abundant, non-critical material. And it's chemically inert, unaffected by acids, detergents, or wastes from home garbage disposal units. It's the one pipe that *never wears out!*

NATIONAL CLAY PIPE MANUFACTURERS, INC.
1520 18th St. N. W., Washington 6, D. C.
206 Connally Bldg., Atlanta 3, Ga.
100 N. LaSalle St., Rm. 2100, Chicago 2, Ill.
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ESSENTIAL • ECONOMICAL • EVERLASTING

Vitrified
CLAY
PIPE
NEVER WEARS OUT!

C-253-5A

SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 25 | **May, 1953** | **Number 5**

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W. H. Wisely, *Editor*, 325 Illinois Building, Champaign, Illinois

Herbert P. Orland, *Associate Editor* Dr. F. W. Mohlman, *Advisory Editor*

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. . . take the Jamaica, Long Island Sewage Treatment Works for example —

In 1941, the New York City Department of Public Works installed eight 120′ dia. Dorr Clarifiers equipped with skimming arms for final sedimentation at the Jamaica Sewage Treatment Works. Overall plant design capacity is 60 MGD utilizing the modified aeration process.

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1952 Literature Review

A CRITICAL REVIEW OF THE LITERATURE OF 1952 ON SEWAGE, WASTE TREATMENT, AND WATER POLLUTION

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This first of two sections of the review deals with analytical methods, sewage, and radioactivity. The second section, dealing with industrial wastes and water pollution, will be published in the June, 1953, issue of This Journal.

ANALYTICAL METHODS

Biochemical Oxygen Demand

Busch and Sawyer (7) made a detailed comparison of B.O.D. values obtained when the dissolved oxygen was determined by both the regular Winkler and a polarographic method. In this study, both a synthetic sewage and six types of industrial wastes were used. In the polarographic method a single potential technique was used, which eliminated residual current measurements. Only one calibration curve was necessary for the series of different substrates. Waste sulfite liquor was found to interfere with the polarographic dissolved oxygen determination, whereas both tannery waste and spent sulfite liquor gave low results with the Winkler method. The k and L values computed from daily determinations on the synthetic media indicated the validity of using the dropping mercury electrode for such studies.

Ingols (24) studied the toxicity of both Cr^{+3} and Cr^{+6} on the B.O.D. as determined by three different methods: (a) dilution B.O.D., (b) manometric B.O.D., and (c) nitrate B.O.D. by nitrate reduction using nitrate as a source of oxygen. Concentrations of Cr^{+3} and Cr^{+6} as high as 20 p.p.m. had little effect on the manometric B.O.D. In the dilution B.O.D., Cr^{+3} was found to be more toxic, whereas with the nitrate method the Cr^{+6} had the greatest effect.

Snow (51) made use of sulfite to remove excess chlorine from chlorinated sewage samples in determining the effect of chlorination on B.O.D. removal. He found that incubated dilutions showed no measurable lag phase due to chlorine toxicity to the seeding organisms and also no measurable oxygen demand due to the excess sulfite. Larionova (33), in studying the effect of trinitrotoluene on biological oxidation, found that 25 to 80 p.p.m. reduced such oxidation 5 to 30 per cent.

Jaeger and Niemitz (25) studied the B.O.D. of sewage by the use of Warburg apparatus. The mean deviation in the 24-hr. B.O.D. values of nine samples was 4.2 per cent and the maximum deviation 7.3 per cent. For routine analyses 24-hr. B.O.D., and for more accurate work 48-hr. B.O.D., were recommended. Comparison of the direct with the dilution method showed that 24-hr. Warburg B.O.D. of sewage was 74 and 53 per cent of the 5-day B.O.D. using tap and seeded dilution water, respectively, and corresponding values for trickling filter effluents were 59 and 38 per cent, respectively.

The B.O.D. of 25 synthetic organic chemicals was determined by the dilution method at intervals over a period of 50 days by Lamb and Jenkins (32). Compounds of similar families were not oxidized biochemically at the same rate, neither were they oxidized at the same rate as sewage. It was concluded that acclimitized seed was better than settled sewage for the determination of B.O.D. of these chemicals.

Skrindle and Sawyer (50) concluded that the Warburg respirometer was not well adapted to the measurement of B.O.D. of dilutions of wastes corresponding to those allowed in natural bodies of water. Results obtained with higher concentrations of waste did not correlate well with the results obtained by the standard incubation test. However, they found the Warburg respirometer valuable for determining the treatability and toxicity of wastes.

Oxygen Consumed

Czensny (10) made a comparison between the permanganate oxygen consumed and the biochemical oxygen demand, using pure organic compounds. As would be expected in some cases, the oxygen consumed values were higher than the corresponding B.O.D.'s. The author gives a detailed discussion of both parameters and an interpretation of the results obtained by each. Cardone and Compton (8) studied the dichromate oxidation of a number of organic compounds in 50 per cent by volume of sulfuric acid. The oxidation was carried out in a boiling water bath, the heating period varying with the type of organic compound being oxidized. The residual dichromate was determined spectrophotometrically at 340 and 850 mμ. Theoretical oxidation of some glycols, formaldehyde, and formic acid was obtained. Dayras (11), in his study of the permanganate oxygen consumed test, pointed out the importance of keeping constant the various factors involved if concordant results are to be obtained. In the oxidation of ethyl alcohol with dichromate, Ferrari (14) found that the ratio of H_2SO_4 to H_2O in the oxidizing mixture must be 1 to 3 or higher.

Dissolved Oxygen

Freier (15), in the determination of dissolved oxygen in water, substituted o-tolidine for the starch indicator in using essentially the Winkler procedure. Wickert and Ipach (54) reacted dissolved oxygen with ferrous iron in an acid solution in the presence of potassium thiocyanate. The color development was compared with standards containing known amounts of iron.

Kjeldahl Nitrogen

A number of papers were published in the past year on the analytical determination of the various forms of nitrogen. Middleton and Stuckey (42) were able to recover quantitatively as NH_3 the nitrogen from a wide range of heterocyclic compounds by using a mercury catalyst. In their work, they kept the final ratio of Na_2SO_4 to H_2SO_4 constant by the addition of acid corresponding to the amount of acid consumed in the reaction. Formulas are given for calculating the necessary acid additions. They also added glucose to accelerate the breakdown of simple pyridine derivatives. McCutchan and Roth (38), by using a preheating step with thiosalicylic acid, were able to re-

duce the nitrogen in nitro compounds to NH_3. Reid (44), using the Hengar procedure, determined Kjeldahl nitrogen on a micro-scale using an all-glass apparatus. The method gave results comparable to the macro-procedure on raw sewage and slimes. Rosicky (45) prevented foaming in the Kjeldahl procedure by addition of a mineral or fuel oil to the flask before making it alkaline with NaOH. Zinneke (55) used a mixture of Se powder, $CuSO_4$, HgO, and anhydrous Na_2SO_4 for the decomposition of nitrogen-containing compounds. A special apparatus is described.

Nitrate Nitrogen

Hahn (18) found that nitrates could be determined in the presence of large amounts of calcium and magnesium if Versene was added to the KOH alkalizing solution to sequester these two elements. Broach and Testerman (5) state that in order for the reaction between nitrate and phenoldisulfonic acid to take place the sample must be absolutely dry. The presence of hydrated or hydroxy compounds interferes, giving low results due to the evolution of nitrogen oxides. De Salas (12) determined nitrate polarographically in the presence of uranyl ions (sensitivity of method not given). Nitrites must be eliminated with sulfamic acid prior to the determination. Chloride ion will not interfere, but fluoride in concentrations greater than 2.5 p.p.m. caused interference. Costa (9) determined nitrates by the addition of resoreinol to an acidified sample. The mixture was heated at 112° C. in a bath of 50 per cent $CaCl_2$ for 30 min. After standing 24 to 48 hr., the color was compared with standards prepared in a similar manner. The limit of detection is stated to be 0.03 gamma of nitrate nitrogen per ml. Nitrites interfere with the method. For the detection of nitrates and nitrites, Barnes (2) used, as reagent for the detection of nitrates, a sulfuric acid solution of N-(1-naphthyl) ethylenediamine·HCl. A sensitivity of 2.5 gamma of nitrate N per ml. is claimed. About 0.25 gamma can be detected.

Ammonia Nitrogen

Kruse and Mellon (30) proposed the use of the pyridine-pyrazolone reagent for the determination of free NH_3. The purple color formed is extractable and the method is sensitive to 0.025 to 2.5 p.p.m. Interference by CN^-, CNO^-, and CNS^- may be removed by first passing the sample through an anion exchange resin. Sijderius (49) found that for NH_3 concentrations below 0.2 p.p.m. the relation between concentration and the extinction coefficient was not linear. When a known amount of NH_3 was added to the sample so that the reading was greater than 0.100, a straight line could be obtained after deduction of the blank. A series of standards may be made up containing increasing amounts of NH_3. The Nessler reagent of Urbach was used. Meleshko and Mazo (41) prepared ammonia-free water by passing distilled water over a sulfonated cation resin (name not given). Oxidizing substances are also removed.

Organic Compounds

Many papers were published during the year on the determination of organic compounds that might be of interest to sanitary chemists. Some of the more pertinent are considered. Braus *et al.* (4) presented a schematic analysis for the determination of the various organic groups of compounds that might be present in industrial wastes. After adsorption of the organics on activated carbon, the carbon is dried and extracted with chloroform or ether. This extract is separated into phenolic, acidic, amphoteric, and water-soluble non-volatile compounds. The application of this scheme to the analysis of five organic industrial wastes was illustrated. Kroner *et al.* (29) determined pyridine and pyridine-base compounds in surface waters and industrial wastes. The sample is first dis-

tilled from an alkaline medium. The pH of the distillate is adjusted to 6.8 to 8.0 and benzidine hydrochloride is added, followed by n-butyl alcohol. The color reaction is carried out in the alcohol layer upon the addition of cyanogen-bromide. The reaction is sensitive to 0.005 p.p.m. of pyridine and can be used in the range of 0.005 to 1.0 p.p.m. Soloway and Wilen (52) improved the ferric chloride test for phenols by using pyridine as an alkalizing reagent and extracted the color formed with either chloroform, benzene, or toluene. Hill and Herndon (21) reinvestigated the use of the p-nitrosodimethylaniline method for the determination of phenols. They obtained greater sensitivity by extracting the color with either CCl_4 or isoamyl alcohol. A sensitivity of 5 p.p.b. is claimed for the method. In the determination of chlorinated o-cresols, Gardner (16) concluded that unchlorinated o-cresol and 4-chlorocresol produce compounds with similar absorption characteristics when reacted with Gibbs reagent. Reaction compounds with similar absorption characteristics also are given by 6-chloro-o-cresol and 4,6-dichloro-o-cresol. If phenol is absent, o-chloro substitution products can be detected in o-cresol by taking two readings with different filters. Medin and Herndon (40) determined naphthalene by extraction with chloroform and reaction with aluminum chloride. Moisture must be absent. The accuracy of the determination is claimed to be ±5.6 per cent. Hermanowicz and Matejak (20) determined fats in sewage by evaporating the sample (acidified to pH 1.0 with HCl) to dryness. The residue is extracted with petroleum ether in a specially-designed apparatus, the petroleum ether evaporated, and the fat weighed. Loewus (34) improved the "anthrone" method for the determination of carbohydrates by substituting a 2 per cent solution of anthrone in ethyl acetate for the formerly used reagent of 0.1 to 0.2 per cent solution in sulfuric acid.

Color and Turbidity

The determination of color and turbidity in industrial waste waters is still in need of study. Rudolfs and Hanlon (46) made a study of the determination of color in industrial wastes in the presence of suspended solids. Their research was directed along three main lines: (a) expressing the effect of suspended solids on the color characteristics of industrial wastes, (b) using the light absorption properties of such wastes for calculating their concentration in stream water, and (c) an investigation for projecting industrial waste color characteristics to stream conditions. They present a method for expressing the color characteristics of industrial waste suspended solids in terms of the visual hue and the degree of light absorption. Beer's law was adapted to the light absorption properties of polluted streams for the purpose of calculating the concentration of two or more polluting wastes. Staats (53) reviewed the measurement of color and turbidity, and elaborated on those methods which offer greatest promise and discussed standards for measurement of these two parameters.

Metallic Ions

The determination of metal ions in drinking waters and industrial effluents is an important field of investigation. Sacchetta and Machado (47) were able to detect 0.2 p.p.m. of arsenic by evaporating the sample to dryness and redissolving in dilute HCl. When a copper wire is inserted in the solution, a gray coloration due to formation of As_2Cu_3 is apparent.

Hansen (19) determined chromium by evaporating the sample in a nickel dish in the presence of Na_2CO_3 and KNO_3. On fusion, the Cr^{+3} is converted to Cr^{+6}. The fused mass is leached with distilled water and filtered. The filtrate is added to a 1 per cent solution of $KClO_4$ containing H_2SO_4. After boiling, the color is developed by the addition of diphenyl-

carbazide. Saltzman (48) carried out the oxidation of Cr^{+3} in an acid solution with $KMnO_4$. The excess permanganate was destroyed by the addition of sodium azide. The color developed with diphenylcarbazide was stabilized with a phosphate buffer.

Noll and Betz (43) removed interference from iron, zinc, and lead in the determination of copper by reducing the strength of the sodium diethyldithiocarbamate reagent to 1 per cent of that usually used. They also used 0.25N NH_4OH as an alkalizing reagent. Hogl and Sulser (22) prevented the adsorption of Cu, Pb, and Zn on sample containers by the addition of 0.5 per cent of glacial acetic acid. This step may possibly eliminate low values previously obtained for these elements.

In the determination of calcium with the flame photometer, Kohnlein and Lucke (26) found that the presence of phosphates interfered in the method, and that they must be eliminated or the calcium precipitated as the oxalate before its determination by this method. Mackereth (35) was able to determine from 10 to 100 gamma of calcium by reacting it with an aqueous solution of pierolonic acid. The precipitate is dissolved in 60 per cent ethyl alcohol and compared with standards similarly prepared. Koroleff (27) determined calcium in sea water with chloranilic acid. A 0.1 per cent solution of sodium chloranilate buffered at a pH of 7.8 is added to the sample. After standing for 2 hr. the solution is filtered and the absorption read spectrophotometrically at 550 mμ. Waters containing more than 3 per cent chloride must be diluted. Interference due to Mg is eliminated by buffering at a pH of 7.8.

Glemser and Dautzenberg (17) studied the determination of magnesium with titanium yellow and found that the amount of the reagent must be varied according to the Mg concentration. They also used a protective colloid, "Polyvoil," to stabilize the colored adsorption colloid.

Halogens

Marks and Chamberlin (37) made a study of the determination of chlorine in metal finishing wastes. They found that in the determination of Cl_2 in cyanide wastes, when the heavy metal cyanides were absent, the amperometric titration, the o-tolidine method, and the iodometric titration were suitable. If heavy metal cyanides are present, then the amperometric titration is indicated. This method should also be used when chromates are present. Marks (36) also discussed the principles and application of the amperometric determination of chlorine in water and pointed out its advantages over other methods. The method also will determine total available bromine, but is not precise in differentiating free from combined bromine. Asmus and Garshagen (1) also studied the determination of Cl_2 or Br_2 by the well-known reaction of these halogens in the presence of pyridine and a primary amine. McEwen and Grant (39) used o-dianisidinedihydrochloride as an indicator in the determination of free chlorine.

The determination of iodine in microquantities in water solution was studied by Kramer *et al.* (28). They found the amperometric method to be accurate to ±0.01 p.p.m. in the range of iodine concentrations from 0.2 to 2.0 p.p.m. The determination can be made at the pH range usually encountered in water supplies, which is advantageous when determining germicidal properties. No evidence of the reaction between iodine and ammonia to form iodoamines was found under the experimental conditions used. Phosphate buffers interfere in the stabilization of iodine residuals.

Cyanogen Compounds

The analytical determination of cyanide in polluted waters and industrial wastes is still under study, as many variables have not been satisfactorily solved. Huditz and Flascher (23) collected considerable data to show that CN^- could be titrated with a standard nickel solution in the presence of hal-

ides, using "murexide" as an indicator. Best results were obtained by adding an excess of nickel solution and back-titrating with a standard solution of ethylenediaminetetraacetic acid. Kruse and Mellon (31) proposed methods for the determination of cyanide, cyanate, and thiocyanate in sewage. Cyanide was determined by the pyridine-pyrazolone method in the range of 0.04 to 2.0 p.p.m. The thiocyanate was complexed as a di-pyridine-copper (II) thiocyanate, cyanide interference being removed previously by boiling the acidified sample. They determined cyanate with pyridine-pyrazolone reagent at pH 3.7 (the pH used for the CN^- determination with the reagent was controlled at 6 to 8). Other interfering elements are removed by cation exchange resins. Brooke (6) proposed a method for the determination of CN^- which does not require preliminary distillation and is sensitive in the range of 0.5 to 3.0 p.p.m. The method is based upon the fact that when an alkaline solution of the palladium complex of alpha-furildioxime reacts with cyanide, the alpha-furildioxime is released from the complex and will react with nickel to give the familiar red color.

Sulfur Compounds

Bethge (3) developed a method for the determination of sulfide which is claimed to be as satisfactory as the well-known methylene-blue procedure. The sulfide is absorbed in a zinc acetate solution. Ammonium molybdate and phosphoric acid are added; the color formed is read at 700 mμ. Duniez and Rosenqvist (13) oxidized the sulfide to sulfate with an excess of a standard solution of KClO. The excess hypochlorite was then determined iodometrically. The method can be used for determining sulfide concentrations in the range of 0.6 to 3.2 mg. per liter.

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SEWAGE

Sedimentation and Mechanical Filtration

Clifford and Windridge (22) report, on the basis of hydraulic model studies on various types of inlets for sedimentation tanks, that weirs are the least efficient, large inlet ports are better than small ones, and that the best design is inlets baffled with eddy buckets. Escritt (31) gives an excellent review of the basic design principles affecting the design of sedimentation tanks. Muller-Neuhaus (84) presents a theoretical discussion of the factors affecting settleable solids removal and the relation between settling and flocculation.

Thomas and Dallas (117) describe the results obtained with a model settling tank with radically sloped bottom and provided with dentated weir troughs located at quarter points. Comparison with a conventional tank showed that for equal flow rates and with three-fourths the detention time, the radically sloping tank gave nearly the same efficiency.

Knopf (72) claims that clarification depends on the capacity (detention time) of the settling tanks and not upon the surface loading. When flocculation occurs in the settling basin the detention time is an important factor and the quantity of suspended matter in the effluent is a function of the detention time. In general, long and flat-bottomed tanks give better flow relations and are less subject to disturbance than basins with high length ratios. Thomas and Archibald (118) determined the magnitude and effect of horizontal mixing in pipes and tanks by the use of radioactive tracers and pointed out the advantage of this technique over the methods used previously.

Two papers appeared on rapid and slow filtration, respectively. Pettet, Collett, and Waddington (88) state that "continuous operation for seven months of two semi-scale rapid gravity filters containing, respectively, 2 ft. of graded sand and 2 ft. of graded anthracite, showed that by filtration of humus tank effluents at rates of application of 240 g.p.h. (U.S.) per sq. ft., the content of suspended solids could be reduced by 72 to 98 per cent, with accompanying reductions in B.O.D. There was no significant difference between the quality of effluents produced by filtration through sand and anthracite."

Biological Filters

It is apparent that the trend in the biological treatment of domestic and organic industrial wastes is in the direction of trickling filters. However, considerable information on the major factors which influence the efficiency of trickling filter performance is still lacking. The literature reports on attempts

to define the influence of such factors as temperature, pH, recirculation, organic loading, ventilation, alternating double filtration, rate of distributor rotation, and detergents, so that the plant performance may be predicted with reasonable precision. Hardenbergh and Rodie (47) have illustrated the effects of loadings and recirculation rates on trickling filter economy. Utilizing the National Research Council trickling filter efficiency formula, they have given in detail illustrative examples of the use of the formula for single-stage and two-stage filters. From these examples it is possible to generalize that: (a) for single-stage filters an increase in the recirculation ratio above about 1:1 may not increase filter efficiency sufficiently to justify the necessary increase in settling tank capacity; and (b) for two-stage filters an increased recirculation ratio will produce somewhat greater efficiency. Even in the latter case it is doubtful that a recirculation ratio greater than about 1:1 will increase the efficiency enough to justify the additional cost of increased clarifier capacity. It is pointed out that the use of two-stage filter with a low (0.5 to 2.0) recirculation ratio will produce B.O.D. removals to the degree required to meet most conditions. A report by Walton (125) on the performance of four trickling filters seems to further substantiate the validity of the NRC's filter efficiency formula. The paper includes a plot of filter loading *vs.* per cent B.O.D. reduction by the filter and secondary clarifier, which data are compared with the NRC formula curve. As predicted by the NRC authors, the results based on monthly averages were much more consistent than were those based on single observations. However, the fact that the formula is most applicable to average conditions makes it a valuable tool in predicting the operational efficiency, inasmuch as most plants are designed for average conditions. Heukelekian *et al.* (53) studied an experimental plant consisting of two high-rate trickling filters 15 ft. in diameter and 5 ft. deep in order to compare the efficiency of B.O.D. removal per unit volume of filter media for series and parallel operation. The filters were operated in parallel for two years, then in series for two years. Recirculation ratios of 2.0 to 10.2 were practiced, and the B.O.D. loadings varied from 0.8 to 5.5 lb. B.O.D. per cu. yd. per day, providing a wide range for comparative purposes. The total hydraulic load was 17.5 m.g.a.d. during parallel operation and 21.7 m.g.a.d. during series operation. A comparison of the operating data showed that series operations can accommodate greater B.O.D. loadings and provide lower B.O.D. values in the effluent than can parallel operations. Below 2.5 lb. B.O.D. per cu. yd. per day series operation produced constant B.O.D. values in the effluent, but the effluent B.O.D. increased with loadings above this value. When operated in parallel the effluent B.O.D. increased with increased loadings above 1.0 lb. Continuing studies (127) on alternating double filtration in England have shown that the rate of the distributor rotation will affect the efficiency of B.O.D. removal. A distributor rate of one revolution in 15 min. produced greater average removals than were obtained by a rate of one revolution in 1 to 4 min. It was also shown that the omission of the humus tank between the two filters had some effect on the quality of the effluent produced. During a 6-month period the average efficiency of the two filters alone without the tank was 73 per cent, and with the tank 77 per cent. Including the effect of the secondary humus tank the respective figures were 82 and 87 per cent. Experiments on the treatment by biological filtration of sewage containing spent gas liquor are also being continued. It has been shown that the presence of 0.5 per cent by volume of the liquor in domestic sewage will increase the effluent B.O.D. by about 50 per cent. An unusual and interesting theory on the performance of trickling

filters has been expounded by Escritt (30) who indicates that the best results are obtained when the rate of flow per unit area of filter media is such that the maximum moisture content of the media is obtained. While this reasoning would obviously break down when flooding occurs, it was shown that a peak of 18 gal. (Imp.) retained per cu. yd. occurred when 450 gal. per day per cu. yd. (1.09 m.g.a.d.) were applied to the Minworth alternating double filtration beds. At a volumetric loading of 100 g.p.d. per cu. yd., 7.5 gal. were retained in a cubic yard of medium; at 1,000 g.p.d., 13 gal. were retained. The paper also included data showing the time taken for liquid to pass through the filters at various rates of flow. At 100 g.p.d. per cu. yd., the mean contact period was found to be about 110 min. in a 6-ft. deep filter; at 1,000 g.p.d. per cu. yd., about 20 min. Fairall (34) has computed the probability distributions of the B.O.D. removal efficiency of two trickling filters. Aside from revealing that the efficiency data are normally distributed when the volumetric loading, temperature, and filter bed are held constant, no conclusions may be obtained from this study.

Horasawa (57) has presented one explanation of the mechanism of the trickling filter process. He classified the organisms found on filter media into three groups: (a) filter film organisms (those forming the film itself); (b) film surface organisms (those which normally predominate at the film surface; and (c) filter cleaning organisms (large-sized organisms preying upon the film). It is postulated that the dissolved organic matter in sewage is absorbed biologically by the filter film organisms for assimilation and stabilization. The organic matter removal rate depends upon the time of contact, the temperature, and the sewage concentration. The suspended and colloidal solids are adsorbed physically on the film surface and then removed biologically by the film surface organisms, especially the protozoa. The adsorption is performed rapidly, resulting in the removal of most colloidal and suspended solids in the upper strata of the filter.

An unusual trickling filter plant has been described by Haack (45). The plant utilizes three-stage filtration in that it consists of a primary clarifier, low-rate filter, secondary clarifier, recirculating (high-rate) filter, tertiary clarifier, low-rate filter, and final clarifier. Although data on loading rates are not presented, it is noted that the over-all plant B.O.D. reduction averages 85 to 90 per cent, a remarkably low efficiency for such complex treatment. In the example given, the first-stage filter and clarifier removed 53 per cent of the applied load; the high-rate filter and clarifier, 82 per cent; and the third-stage filter and clarifier, 6 per cent—at a time when the over-all efficiency was 92 per cent. An arrangement with a near-by oil refinery provides for supplying the treatment plant effluent to the refinery for cooling water. The refinery pays $900 per month for the effluent, provided that the average weekly B.O.D. is below 60 p.p.m. For B.O.D.'s above this figure there is a corresponding reduction in price.

A general discussion of temperature effects on the biological life within trickling filters has been presented by Schroepfer *et al.* (98), who surmised that the temperature of a filter is a major factor affecting the filter efficiency. The authors collected operating data from 5 plants and in each case plotted the sewage temperature against the efficiencies of B.O.D. removal in an atttempt to evaluate numerically the temperature effect. The temperature range varied from 20° to 26° F. and the loadings from 288 to 17,500 lb. B.O.D. per acre-foot per day. An attempt was made to reduce the loading effect by grouping the data within certain loading ranges for each plant. In the 13 groups of data studied, a trend towards increasing efficiencies of B.O.D. removal with increasing sewage temperatures was apparent. The trend was assumed to be linear, and for each group

the slope of the line of best fit was computed. The slopes ranged from 0.18 to 0.74 (in per cent increase in efficiency per °F. increase in temperature). Unfortunately, the significance level of the slopes was not indicated. Arranging these data into groups according to B.O.D. loading enabled the authors to conclude that the temperature effect is of decreasing importance as the organic load on the filter increases. Further, the volumetric loading appeared to have little to do with the temperature effect. Johnson (62) investigated the flow of air in four covered and one uncovered trickling filters of 6- to 8-ft. depth and of 30- to 55-ft. diameter. The field data collected included dry- and wet-bulb air temperatures, barometric pressures, sewage temperatures, wind velocities, and bulk air flows through the filter media. Comparisons of the data obtained from each filter demonstrated relationships between the bulk air flow in the media and the actual draft, and the differential in sewage and air temperatures. The plotted data showed that natural drafts result from the wind and the stack effect. The temperature difference between the sewage and the outside air created drafts from air density differences. For covered beds better ventilation is obtained with larger openings at the top of the house. The author estimates that 0.1 cu. ft. of air per minute per square foot of filter area is required for the average filter and states that a temperature difference between the sewage and outside air of 5° F. will assure this rate of flow without the influence of wind. The present trend in Poland (113) is toward closed, artificially ventilated trickling filters, apparently as a result of the severe winter conditions in that country. However, an open filter is reported not to have frozen when the air temperature dropped to −33° C., probably because an 11-min. dosing cycle was used.

The prevalence of *Psychoda* breeding in Akron's trickling filters has been partially responsible for claims of $130,000 in damage suits, a condition which resulted in studies (97) being made on control measures. Plant-scale tests employing various larvicides and adulticides were instigated in 1947 and continued during each of the summer breeding periods through 1951. DDT, Rothane, Chlordane, Lethane 384, Pyrenone, BHC (benzene hexachloride), Nifos-T (tetraethylpyrosphosphate), and fuel oil, either singly or in various combinations, were tested as adulticides. Pyrethrum, Pyrenone, Lethane 384, kerosene, Nifos-T, pentachlorophenol, Chlordane, DDT, and BHC were tried as larvicides. The methods of application included (a) adding to the applied sewage, (b) "fogging" at the trickling filter bed surface, and (c) spraying of the bed surface. The most effective control measure was found to be 9.0 gal. per application of 11 per cent gamma isomer BHC applied early in the breeding season, followed by 4.5 gal. per application at approximately monthly intervals. The beds were rested for 2 hr. following application. The filter B.O.D. efficiency was not impaired by any of the chemical applications. Spiess (104) reported on 15 years of failure in attempts to combat filter flies, followed by tentative success. Attempts to control prolific hatches of *Psychoda* by flooding, by spraying and burning, and by applying DDT, Chlordane, "497," BHC, "D–N–289," TEPP (tetraethylpyrophosphate), and Chem-Larv were successful for limited periods of time only, or else were useless. High-grade fuel oil containing 4 per cent Lethane 384 "special" was completely effective for 30-day periods, but it was reported used only on two occasions. Effective control was finally obtained by dosing the filter with trichlorobenzene at intervals of 7 to 11 days, whereupon a decrease in the effluent quality and an increase in filter clogging became apparent. This chemical is a poison and should be used with due regard to the effects upon the receiving stream.

A study of the biology and control of

Anisopus fenestralis, a fly associated with sewage filters, was made by Hawkes (49). Experiments showed that limiting food concentration had an effect on the life cycle of this organism. The limitations and factors influencing the method of counting of flies by tray trapping are discussed. In daylight and in cold weather the flies tend to keep to the warm dark depth of the filter. Reversal of these conditions brings the flies to the surface. The maximum abundance of this organism is during spring, being lower in summer, increasing again during autumn and winter. Benzene hexachloride applied as a dispersible powder was effective in the control of the fly. The same author (50) reported the results of additional studies on this fly by trapping the adult flies on sticky surfaces suspended over the filter bed, which gave a better index of aerial density than the tray trapping method. It was shown that during colder periods the egress of the fly from the bed was inhibited. In general, air temperature of below 52° F. limited the aerial density of this organism. Other factors influencing the aerial density were wind velocity and light.

Calaway *et al.* (17) show some of the basic biological, chemical, and physical interrelationships existing in intermittent sand filters used to treat sewage. The test filter consisted of $\frac{1}{800}$ acre of sand 30 in. deep with a uniformity coefficient of 3.3 and an effective size of 0.31 mm., dosed regularly with settled domestic sewage of about 100 p.p.m. B.O.D. The dosing rates were 150,000 and 300,000 g.p.a.d. Sand samples were secured from varying depths in the bed to study the number and distribution of (a) general aerobic heterotrophic bacteria, (b) zooglea-forming bacteria, and (c) coliform organisms and fecal streptococci within the sand. Fourteen species of general heterotrophic bacteria were isolated from the sand with members of the genera *Flavobacterium* and *Bacillus* predominating. The zooglea-forming bacteria were concentrated in the upper layer of the bed and could not be detected below the 12-in. level, a circumstance which corresponded with a high percentage of B.O.D. removal in the upper layers. The numbers of coliform organisms exhibited a continued decrease throughout the filter depth and demonstrated a 95 per cent over-all removal, whereas the fecal streptococci showed only 20 per cent removal. Attempts to show that decreases in enteric bacteria result from the presence of antibiotic-producing microorganisms, met with failure. All species of bacteria showed a logarithmic decrease in numbers with filter depth; however, all species did not appear to decrease at equal rates.

An interesting laboratory device for the purpose of studying the susceptibility of various industrial and domestic wastes to trickling filter treatment has been developed by Gloyna *et al.* (42). This so-called trickling filter "equivalent" consists of 2¼-in. diameter by 24-in. long rotating plastic tubes inclined slightly from the horizontal. Raw wastes are fed into the upper end and microbiological slime films develop on the interior walls in a manner parallel to those on trickling filter rocks. For experimental work some advantages claimed for the device include (a) less space required, (b) greater accessibility and more easily maintained, (c) the effective active surface is directly measurable, (d) slimes may be completely removed, (e) activation and recovery occur more rapidly, (f) no clogging, and (g) portability. Data from experiments using synthetic sewage of 250 p.p.m. B.O.D. indicate removal efficiencies comparable with a conventional laboratory trickling filter. Tests using I^{131} showed that the rotary tubes have a slightly more rapid flow-through time. Keefer and Meisel (70) have presented an outstanding example where the results of preliminary studies justified enlargement of plant capacity with relatively little expenditure. One year of plant-scale experiments were conducted at Baltimore to determine the

performance of existing trickling filters when the loading is increased. The filters are 8.5 ft. deep and the medium is 1- to 2.5-in. trap rock. The conclusion drawn from the studies indicated that the filter capacity could be materially increased above the 3.5-m.g.a.d. operating rate without detrimentally affecting the effluent quality. Consequently, the 30 acres of existing filters were equipped with 50 rotary distributors to increase the volumetric loading on the beds. Tests made to check the original experiments showed that B.O.D. removals in excess of 80 per cent were obtained with loadings ranging from 2.68 to 13.53 m.g.a.d. (375 to 1,905 lb. B.O.D. per acre-foot per day).

Some of the difficulties encountered in constructing new trickling filters include (a) breakage and misplacement of underdrain blocks, (b) breakage and segregation of the media, (c) leveling the surface of the bed, and (d) obtaining satisfactory rock for the media. Fort Worth, Tex., has circumvented these troubles during recent construction of eight new filters (78). This report presents several construction features of interest, and the specifications for the filter stone and for placing the stone. A brief history of high-rate trickling filters, together with mention of some principles and advantages of this method of secondary sewage treatment, has been outlined by Flood (37).

Activated Sludge

Fair and Thomas (33) showed, on the basis of data collected from 19 diffused air activated sludge plants in this country, that there existed a relationship between the efficiency of B.O.D. removal and the loading parameter developed by them, which relates the daily pounds of B.O.D. in the sewage per 1,000 lb. of suspended solids in the mixed liquor per hour of aeration.

Popel (90) developed formulas from which monographs were constructed for predicting the performance of aeration tanks. The percentage of 5-day B.O.D. remaining after t hours aeration was related to p.p.m. suspended solids in the mixed liquor, the area of air-water interface per unit volume of tank, and α, a function of suspended solids and aeration intensity. Theoretically calculated values are compared with actual performance figures from European and American plants. The mean deviation is 22.5 per cent, which is reducible to 14.6 per cent when discarding non-representative values.

In laboratory-scale experiments, Smith (101) found that the efficiency of B.O.D. removal in an activated sludge system is a function of the total sludge mass present. Within the range of about 70 to 94 per cent volatile solids, no variation in the ability to remove B.O.D. was observed. The degree of B.O.D. removal is closely related to the applied B.O.D. load and the total weight of sludge in the aeration tank. He combined the variables into a sludge weight loading parameter, X, expressed as the 5-day B.O.D. applied daily per 1,000 lb. of sludge per hour of aeration. Using the generalized relation of Fair and Thomas (33), he obtained

$$E = \frac{100}{1 + 0.00266\ (X + 45)^{0.880}}$$

where E is per cent efficiency of B.O.D. removal and X is the loading parameter.

McKinney and Horwood (82) isolated five floc-forming organisms, other than *Z. ramigera*, from activated sludge. These organisms and *A. aerogenes*, which also forms a floc, were studied and found to produce B.O.D. reductions ranging from 66 to 88 per cent in 24 hr. McKinney (81) proposes the theory that bacterial flocculation is brought about by reducing the electrical charge below the critical level and allowing the cells to come into contact through agitation. The bacterial surfaces then undergo direct chemical reaction to form a solid bond between cells.

Holroyd (54) continued his studies on the dynamics of aeration. The effect of surface-active agents on reaera-

tion rate was determined. Surface-active agents were found to depress the reaeration rate. The most pronounced reduction due to surface-active agents was found with diffused air. The layer of surface-active agent acts as a barrier to aeration at the bubble surface. With stagnant surface, the effect of surface-active agents on the reaeration rate was less.

The quantity of oxygen which may be transferred to the liquid in an aerating system has been formulated by Eckenfelder (27) in terms of an oxygen absorption rate coefficient. Two methods were suggested for the measurement of this coefficient and Eckenfelder (28) has provided a nomograph to aid in the design of aeration equipment.

Two new modifications of the activated sludge process have been mentioned. Attempts by Babbitt (10) to use a high-oxygen atmosphere gave inconclusive results because the accumulation of nitrogen in the synthetic atmosphere rendered the process impractical. Jenks (61) proposed aeration and mixing in a circular tank in which the flow entered tangentially at the top and was drawn off centrally at the bottom. In this Spirovortex activation process, aeration takes place by the vortex action. With recirculation of flow, aeration through the vortex action was adequate in small tanks, but in large tanks supplementary aeration had to be supplied by recirculating the flow at rapid rates through a biological filter bed 1 ft. deep.

Excellent papers on the operation of activated sludge plants were presented by Haseltine (48), Kalinske and Gillard (65), Tapleshay (116), and Van Kleek (123). Jung (63) discussed the technical developments of the activated sludge process and several of its modifications.

An excellent comprehensive treatise on air diffusion in sewage works was prepared by Anderson (3) and his committee for the Federation. The manual critically reviews the technical practices in the design, operation, and maintenance of porous diffusers.

Lemke (73) presents an air-friction diagram based on the Darcy-Weisbach formula and compares results obtained using the diagram with a number of existing friction diagrams and formulas. An oxygen absorption test developed by the Sanitary District of Chicago for rating air diffusers is discussed by King (71). The test is based on the measurement of the decrease in sulfite concentration from a standard solution. Air rate, temperature, pH, and diffuser submergence are maintained at constant values in the test procedure.

Finch (35) discusses recent modifications in the Sheffield system of bio-aeration and the Simplex surface aeration system in Great Britain. Changes in the shape of the paddle blade, increasing the speed of the paddle, and diminishing paddle immersion depth have resulted in marked improvement in the bio-aeration system. It is anticipated that these modifications at the Sheffield plant will permit treatment of 30 m.g.d. in a plant designed originally to treat 18 m.g.d. It is reported that in the modified Simplex system, a new type cone will enable aeration tank volumes to be reduced by about one-quarter to one-third. A mechanical aeration system known as the "Transuration system," in which aeration is obtained by mechanical agitation from paddles spirally arranged about a rotating shaft, is also described by Finch (36).

The causes of frothing in aeration tanks and the methods of alleviating the trouble have been the subject of much dissension. It seems evident that although synthetic detergents are a factor in froth formation, other factors are also important. Many operators believe that the concentration of solids in the aerator is a deciding factor. Wells and Scherer (128) found that at San Antonio, Tex., frothing started when the aeration solids dropped below 1,400 p.p.m. If the solids were maintained at 2,000 to 3,000 p.p.m., no

frothing occurred with additions of 100 p.p.m. of anionic detergent; even when 250 p.p.m. were added, only a slight frothing was observed. Simpson (100) believes frothing depends on the length of the aeration period, the concentration of detergent, the concentration of aeration solids, the alkalinity, and the presence of nitrites and nitrates. McNicolas (83) reported that frothing seems peculiar to the diffused air process. No froth has been observed on tanks of the Simplex, Haworth, or Kessener systems. He believes that frothing occurs only when the plant is in good condition. Heavily loaded plants do not froth.

Various methods have been proposed to destroy the froth. McNicolas (83) at Burgh of Motherwell and Wishaw, Clyde Park, Scotland, favors spraying a small quantity of mineral lubricating oil on the surface of the tank. Allison (1) at Corpus Christi, Tex., uses a spray of plant effluent. Donaldson (26) found that frothing at the 26th Ward Plant in New York City was controlled by the use of a permanent system of spray piping and by the injection of an anti-foamant into the spray system. Neither the water spray nor the anti-foam chemical alone has been found satisfactory. He also reported that the dirty greasy liquid obtained from aeration tank froth contained on a wet basis, 0.77 per cent total solids, of which about 23 per cent was grease and about 12 per cent alcohol-soluble detergent. Froth from final tanks or from the final effluent of activated sludge contained from 30 to 50 per cent grease. Stevens (112) recommended the use of special, free-flowing, light-colored, nonflammable compounded oil. The use of about 0.5 p.p.m., especially when added to a water spray system, satisfactorily controlled frothing.

The program of sewage treatment plant construction has progressed rapidly in New York City. Steffensen (109)(110) has described the 160-m.g.d. Owls Head plant, designed for high-rate activated sludge. The aeration and settling tank structures are enclosed and ventilated, the exhaust gases from the ventilation system being ozonated. According to Cunetta (25), the Hunts Point plant, designed for 120 m.g.d., treats sewage by either the conventional activated sludge process or by step aeration. The smaller Rockaway plant (103) was designed to handle 15 m.g.d. by the high-rate activated sludge process.

Disinfection

Revocation of NPA order M31 effective November 18, 1952, removed chlorine distribution from governmental control. The order had been in effect since January 23, 1951. Substantial increases in production had supplied chlorine in excess of the demand for a 6-month period prior to the revocation date (8).

A cooperative committee has been formed ". . . to develop a better understanding of the practical and scientific problems in the application of chlorine to sanitation." The group is made up of representatives of the chlorine producing industry, the U.S. Public Health Service, and associations interested in sanitation (9).

Conservation practices in the use of chlorine were discussed at the 1951 Annual Meeting of the Federation (4). The technique of chlorine dosage control within the limits required to produce a satisfactory effluent has been explained, together with a discussion of chlorine demand and special conditions affecting chlorine control. A nomograph based on flow in m.g.d. and chlorine dosage establishes the chlorine demand relationship (115).

Inconsistencies in bacteriological results were reported from 10 New York metropolitan area sewage treatment plants. Investigation revealed that identical chlorine residuals as measured by ortho-tolidine do not effect similar reductions in coliform density as measured by the median M.P.N. (96).

That there are optimum periods during the life cycle of bacteria when chlo-

rine can be administered for maximum B.O.D. reduction has been demonstrated (102).

Studies of recreational waters in Michigan receiving treated sewage effluents indicated a need for improved disinfection procedures in the contributing sewage treatment plants. Plant-scale studies indicate pre-chlorination plus post-chlorination can be controlled with ordinary effort, rigid effluent quality standards may be met consistently, and the confirmed bacteriological test has maximum reliability in reporting coliform density (89).

Fundamental sewage chlorination reactions have been discussed in a review article including information concerning the germicidal efficiencies of di- and mono-chloramine. The effect of pH on the disinfection action of chlorine and other germicides is also described (87).

Beaches in the vicinity of the Orange County (Calif.) Joint Outfall Sewer make seasonal chlorination of the primary treatment effluent necessary. Inconsistencies in bacterial kill were discovered while using ortho-tolidine indicator. Investigation revealed possible advantageous use of the amperometric procedure. Adoption of the amperometric method for residual chlorine determination resulted in treatment of 146 m.g. more sewage in 1951 with 70,000 lb. less chlorine than in 1950. Adequate protection of 28,000 ft. of bathing beach was maintained (52).

Disinfection of digested domestic sewage sludge by chlorination is technically and economically feasible according to Ammon and Wieselsberger (2). Only thoroughly digested sludge should be chlorinated, as actively gasifying sludge requires materially higher chlorine dosages.

Reports concerning the joint industry-municipal plan for the handling of pollution in the Raritan River Valley have received considerable attention. Assessment of charges based on chlorine demand for contributed trade wastes has resulted in confusion over interpretation of presently constituted chlorine demand tests (6).

A comprehensive review of methods used in the preparation of chlorine dioxide has been published (complete to 1952). The information concerns the three classes of reactions used for the preparation of chlorine dioxide; reduction of chlorates, oxidation of chlorites, and the direct oxidation of chlorine. Methods of preparation involving chlorate reduction are of greatest practical importance according to the author. Methods used to remove excess chlorine from finished chlorine dioxide are also discussed (21).

The development of solution feed chlorinators, which started 40 years ago, has been briefly described. This supplies a historical record of those individuals who made original contributions (32).

Sludge Digestion

Mechanism and Factors Involved

Chemical mechanisms by which methane may be produced by bacteria in nature were discussed by Buswell and Mueller (16), showing that production may occur with or without the reduction of CO_2. Fermentation proceeds smoothly and continuously at pH 6.5 to 8.0, regardless of the chemical nature of the substrate, except in the case of hydrocarbons, ethers, and lignins, and complete conversion of the substrate to CH_4 and CO_2 is possible. The effect of the addition of nitrates to a methane fermentation of acetic acid by a highly purified culture was studied by Buswell and Pagano (15) to observe the role of large numbers of denitrifiers previously reported in anaerobic methane fermentation cultures. Denitrification to nitrites and nitrogen gas was found to take place, leading to a complete disappearance of methane from the gases if continued feeding of nitrates and acetic acid was carried out. In later stages of fermentation gas production was diminished in the absence of oxidized nitrogen or oxidizable carbon compounds. Many organisms in cul-

ture were found to be denitrifiers. All were Gram-negative, short, motile rods inactive in fermentation of sugars, and two were identified tentatively as *Pseudomonas* sp. The study suggested that about 49 per cent of nitrate oxygen is available for waste stabilization.

The production of volatile acids during digestion of normal and overloaded seeded mixtures of industrial wastes was investigated by Kaplovsky (66). Spent yeast nutrient, paper white water, and slaughterhouse wastes were seeded with ripe sludge in volatile matter ratios of 20:1, 5.6:1, and 9.3:1, respectively. The overloaded yeast mixture, rich in nutrients, produced acetic, propionic, butyric, and valeric acids, with propionic and valeric acids increasing rapidly after maximum acid accumulation had been reached. The nitrogen-rich slaughterhouse waste produced the same four acids, whereas paper white water with its low nitrogen content produced acetic and butyric acids only. The author concludes that total volatile acids may be used to determine the efficiency of constantly fed slaughterhouse digestions. Stander and Hide (107) found that sulfates had a retarding effect on digestion of distillation residues from production of ethyl alcohol from sugar cane molasses and grape juice. Inoculated material showed a rapid rise in volatile acids due to an unbalance in bacterial activity brought about by large amounts of sulfate. To check this conclusion Stander and Elsworth (106) repeated the study using molasses slops high in sulfates, with de-sulfated slops as a control. A 15.5 per cent decrease in amount of organic carbon converted to CO_2 showed the inhibiting effect of sulfates. At 33° C. gas production was diminished, but volatile acid increase was normal. At 55° C., however, less carbon was converted to gas and volatile acids increased rapidly. Stander (105) was able to control this volatile acid concentration effectively by adding an inoculum derived from raw sewage sludge to overcome bacterial population unbalance. In other tests sulfate contents of 1,380 to 2,700 p.p.m. caused difficulties in preparing an inoculum. Check experiments by Stander and Snyders (108) using re-inoculation as a routine part of the procedure for digesting still liquor, molasses slop, and yeast waste showed volatile acid concentration well-controlled, even at 2,865 p.p.m. sulfates. That bacterial population was concentrated in sludge was shown by a rapid rise in volatile acids following removal of 25 per cent of the sludge on the third day.

Rudolfs and Amberg (93) studied the toxicity of sulfides in the digestion process by batch digestion of paper mill white water seeded with ripe sewage sludge. Nitrogen was added, initial pH adjusted, and various concentrations of sulfite introduced. Gasification was inhibited by sulfide concentrations of 150 to 300 p.p.m. as $S^=$, and retarded even at low concentrations. Sodium sulfide up to 300 p.p.m. (as $S^=$) had no effect on the production of volatile acids, but 82 p.p.m. retarded methane fermentation of sodium acetate. Working with a substrate containing calcium acetate and purified enriched cultures of methane bacteria, Bannick and Muller (12) found that sodium sulfide had no retarding effect on gas production at 780 p.p.m. but inhibition resulted at 3,900 p.p.m. Sodium sulfate at 1,260 p.p.m., however, reduced gas production 70 per cent, although no retarding occurred at 126 p.p.m. The toxic effects of other materials such as hydroxylanine, phenylhydrazine, sodium azide, potassium cyanide, and formaldehyde were reported. Organisms can be acclimated to 15 per cent formaldehyde, and in presence of that chemical produce equimolecular proportions of CH_4 and CO_2.

Alleviation of the observed effects of soluble sulfide was tried by Rudolfs and Amberg (94). Two-stage digestion with intermediate aeration was not considered feasible because sulfate reduction to sulfide continues in the secondary stage. Yeast extract added reduced

sulfate reduction, but had no effect on methane fermentation until CO_2 and N_2 were added to remove sulfides as they were formed. In combination with aeration this procedure permitted a two-fold increase in B.O.D. loadings. At 0.09 lb. per cu. ft. per day a 68 per cent B.O.D. reduction resulted in a three-day period. Stander (106) found the sulfate ion was reduced almost completely by anaerobic fermentation either in mesophilic or thermophilic ranges.

Noordam-Goedewagen, Manten, and Muller (86) reported that methane fermentation of sodium acetate was affected by: (a) pH value, being greater at 6.0 to 6.5 and dropping off at higher and lower values; and (b) sodium sulfite, a concentration of 100 p.p.m. having no effect, but 500 p.p.m. having a distinct retarding effect. This effect was bacteriostatic rather than bactericidal. The pH value had an effect on the inhibitory action of sulfite; at higher pH values, greater concentrations of sulfite were required to give inhibition. Calcium sulfite had a similar though less pronounced effect than sodium sulfite. Calcium acetate fermented more rapidly than sodium acetate because a more favorable pH value could be maintained with the former than with the latter.

The effects of temperature, nutrient addition, and seeding ratio on the digestion of concentrated white water wastes were reported by Rudolfs and Amberg (92). Optimum temperature was found to be 30° to 37° C., with the higher temperature producing more gas but not affecting B.O.D. reduction. Nitrogen deficiency of waste alleviated by the addition of soluble ammonium salts resulted in a 70 to 80 per cent removal of B.O.D. With added nitrogen and phosphorus, and pH control, Rudolfs and Nemerow (95) were able to bring about anaerobic digestion of rope, rag, and jute cook liquor in 6, 4, and 2 days, respectively. Digester loadings of 0.027 to 0.056 lb. B.O.D. per cu. ft. of digester effected 72 to 82 per cent B.O.D. reductions.

The importance of inoculation of industrial wastes with raw or digested sewage sludge was stressed by several researchers. Rudolfs and Amberg (92) found seeding of mill white water necessary. On the basis of volatile matter, one part of ripe sewage sludge to one part of white water was sufficient. Wastes from the manufacture of bakers' yeast from cane sugar molasses and malt containing only specific organisms were studied by Stander (105). A population unbalance not associated with adding raw sewage sludge caused rapid volatile acid production. At 33° C. the addition of an inoculum derived from sewage immediately arrested the rise of volatile acids. At 55° C. a digester failed after 30 days, but the inoculum was ineffective in restoring it.

Bryan (14) experimented with commercially prepared bacteria in order to see whether an overloaded sewage plant could be relieved by offsetting a deficiency of naturally produced organisms and enzymes. Supernatant quality was used as a measure and improved supernatant quality was reported for 60 days after 200 lb. of inoculum had been added over a 40-day period. A 50 per cent decrease in quantity of sludge drawn was reported and the author concludes that the biological industry may be able to supply useful tools. Results of an experiment with another commercial inoculum in a glass model septic tank were reported (7). Suspended solids removal and reduction in B.O.D. were increased by large percentages.

Horasawa (56) showed that municipal night soil digests more readily than fresh human excreta. The difference in the digestibility of these two types of materials is attributed to the dilution of municipal night soil.

Operation and Design

The design characteristics of both unheated and heated sludge digesters, as well as specific operational procedures, were set forth by Van Kleeck (122) in

a thorough discussion of the control of sludge quality.

The effect of ground garbage on digesters was outlined by Simpson (99). Approximately 0.5 lb. of solids per capita per day with a flow of 3 g.p.c.d., results from home garbage grinding. A 56.5 per cent increase in raw sludge necessitates 50 per cent greater digester capacity. Garbage decomposes more rapidly than sewage, with increased gas production and stronger supernatant. It also introduces greater problems in scum and grease. Frequent pumping of raw sludge and two-stage digestion are recommended.

Operational troubles of importance to designers were reported. Blodgett (13) observed, in valved-off sludge lines, gas formation of sufficient pressure to blow gaskets. Heat exchangers set on the floor permitted sludge leaks under the units to cause odors and corrosion. At Dayton, Calihan (18) had bad experiences with incrustation on immersion coils in a digester. At first, water temperatures of 80 to 98° F. were sufficient, but later 130° F. was required to heat the sludge. This accelerated incrustation until a 3-week cleaning job was required. Gas-fired boiler sections deteriorated due to excessive condensation of combustion products. When the system was replaced with a water-bath type heater no difficulty developed in 6 years. Calahan also suggested the need for a new approach to floating cover design, as condensate rots the wooden roof. External heat exchangers at Akron were described by Long (75). Oil lines for a dual-fuel furnace were put together with a joint compound that dissolved in the oil. With the windows shut, exhaust fans produced a vacuum in the building so great that exterior doors could scarcely be opened. Niles (85) reported the effect of silt entering defective sewer joints. Not taken out by the detritors, it settled slowly in the digesters to foul the mechanism in 4 to 9 weeks. A fast pumping rate pulled a cone of fresh solids through the viscous mass and the silt was not removed from near the sides of the tank. A slow rate caused the silt to settle out in sludge lines. After breaking of the thrust bearing at the end of the shaft, the digester was pumped out and fire hoses were used to dislodge the silt. The trouble is expected to get worse.

Sludge Disposal and Utilization

Elutriation

An increased number of barge trips to dispose of digested sludge of low solids content led to elutriation tests of primary digested sludge at New York's Jamaica plant (119). High level digester liquor of 2 to 3 per cent total solids was mixed with 4 to 13 volumes of plant effluent in an improvised single-stage elutriator. Sludge concentration from 3.9 to 7.4 per cent total solids was obtained. The elutriator concentrated the sludge as effectively as a secondary digester with 12 times the volume. Quiescent storage increased sludge concentration to more than 10 per cent total solids. Although the elutriate carried away 5 to 30 per cent of the solids applied, it had no adverse effect on the modified aeration process in use. By maintaining a low sludge blanket in the elutriator and an overflow rate below 400 g.p.d. per square foot, the escaping solids were reduced to 15 per cent of those applied. In the course of the study, digester operation was simplified and it was concluded that full-scale application of elutriation would materially reduce the volume of sludge to be barged to sea.

In a discussion of the paper, Genter lists the purposes of intermediate elutriation, which may be defined as sludge or sludge liquor elutriation between the biologically active and less active storage stages of digestion.

Pumping

Past headaches in pumping heavy raw sludge through 4,400 ft. of 24-in. force main for disposal by barging, were reviewed by West (129). Experience has proven the need for recirculation of stored sludge and dilution

with sewage before pumping, if pumping rates are to be maintained. A sludge averaging about 8.75 per cent solids can then be pumped to a sea-going barge. Freezing of sludge around the walls of unheated sludge storage tanks threatened to damage the tank floating covers and was prevented by floating the covers to the tops of the walls and anchoring them there. The covers have been subsequently left in this position. It would be interesting to know whether explosive or burnable mixtures of methane and air have ever been detected under these fixed covers during warm-weather storage of raw sludge.

Dewatering

Halff (46) experimented with a formula adapted from Fourier's method for solving heat conduction problems in an attempt to correlate the many factors influencing the vacuum filtration of sewage sludges. The developed equation may be used to solve operating or design problems after the formula constants have been determined from laboratory tests. Examples presented by Halff demonstrate that if the time of filter cycle is variable, then the maximum yield is obtained with a minimum final cake thickness and that, within limits, the yield is improved by increasing the time of submergence, and this without affecting the moisture content. Additional tests with different sludges, under varying conditions, will be necessary before final acceptance can be given the method.

Design and operation of sludge drying beds and lagoons for sludge dewatering were discussed by Van Kleeck (124). The advantages gained through use of chemical conditioning of sludge prior to air-drying are given, together with the optimum doses of chemicals.

Cooling, Jones and Pettet (24) conducted a study to determine the effect of passing a current on the dewatering of digested sludge. They found that digested sludge responds to treatment with electro-osmosis. The electro-osmotic permeability was 0.006 gal. per sq. ft. per hr. per volt per inch. The quantity of water removed by electro-osmosis is directly proportional to the quantity of electricity transported, the constant being 0.02 gal. per ampere-hour. The thinner the sludge layer, the more economical in current is the process. In the initial stages the power required to give a certain rate of yield of water increases directly with thickness. If the initial rate could be maintained, the energy required to produce a given low average water content would increase with the square of the thickness. A practical difficulty is the formation of a dried crust on the anode. This reduced the electrical efficiency of the system. The consumption of electricity in the pilot tests was so high that application of the process under practical conditions would be uneconomic. In addition to the cost of power there would be the cost of replacement of corroded anodes and labor to place the electrodes in the beds.

Utilization

An interesting development of the year was the isolation of vitamin B_{12} from activated sludge by the Eastern Regional Research Laboratory of the U. S. Department of Agriculture (55). It has been found that 10 to 15 mg. of this vitamin per ton of animal feed results in a 20 per cent increase in animal weight over feeding with unfortified food. Thus, the resultant decrease in amount of grain required constitutes a substantial reduction in the cost of production of meat. Dried activated sludge has a content of about 3.5 to 4 mg. of vitamin B_{12} per kilogram. This is comparable to the amount required in commercial animal feed supplements. Part of the vitamin was found derived from the raw sewage and part synthesized by microbiological action in the aeration tanks. Improved drying conditions for the sludge should further increase the vitamin content. If dried activated sludge is to be incorporated directly into

feeds, the authors point out that its use must be first approved by the U. S. Food and Drug Administration and the respective state feed control officials.

Van Kleeck (120) presented pictorial evidence of the benefits of sludge fertilization for grass, shrubs, trees, and vegetables on a plot of land fertilized under his direction. Significant growth is illustrated through use of chronological photographs.

The related factors in utilization of sewage sludge as a fertilizer and soil conditioner were described by Van Kleeck (121). The need for intelligent use of both sludge (or any humus material) and mineral fertilizer was emphasized. Lime is needed with sludge, both to correct soil acidity and to precipitate harmful amounts of certain elements normally present, such as copper, aluminum, manganese, zinc, and boron. These elements have been shown to particularly affect the growth of certain vegetables. Also, low application rates (about 10 tons of sludge cake per acre) reduce the harmful effects from these elements. Sludge shredding is urged to increase salability. The dearth of farmyard manure makes the outlook for sludge utilization increasingly encouraging. The regulations on sludge use by the Connecticut State Department of Health are given.

Mechanical Equipment

Laboratory and semi-works equipment, used in the development of a catalytic oxidation method for treatment of aqueous and vapor-phase materials containing low concentrations of a number of types of organic compounds, is described by Green and Moses (43). Evaporation equipment for industrial waste treatment problems was a subject of discussion at the 1951 Industrial Wastes Forum of the FSIWA meeting. The published transcript of the forum (5) provides details regarding equipment used for submerged combustion methods.

Baffa (11) discussed the general theory and principal factors in the corrosion problem in sewage and waste treatment works. McClenahan (80) reports results of extensive tests and experiences with priming and top-coat paints used on metals in the sewage works of the Chicago Sanitary District, and gives formulations for protective coatings that have found favor in the District's maintenance program. French (38) discussed the subject in the light of experience at New York City's treatment plants. As a result of an extensive study of corrosion problems that was conducted at the Back River sewage treatment works at Baltimore covering a period of four years, Keefer and Huston (69) reached the conclusions that: (a) in damp atmospheres containing H_2S, or in enclosures above septic sewage, raw sludge, or digested sludge, metals showing little or no attack at the end of 18 months were stainless steel of American Iron and Steel Institute (AISI) types 410, 430, 304, and 316, aluminum 17ST, nickel alloys, Monel metal, and Inconel metal; (b) in damp atmospheres containing free chlorine none of the metals tested proved satisfactory; (c) stainless steels that proved satisfactory after 31 months of exposure in direct contact with digested sludge coagulated with chlorinated copperas included AISI types 317 and 316, and Armco 17–14 Cu-Mo; (d) stainless steels that proved satisfactory after 31 months of frequent exposure to the spillage of freshly dewatered vacuum filtered sludge cake included Armco 17–7 PH and AISI type 304. Results almost as satisfactory were obtained with AISI type 431 and Armco 17–4 PH.

Major equipment installed at four of New York City's plants are described in articles by Steffensen (109)(110)(111), Cunetta (25), and Soreff (103). The Owls Head plant (12)(13), reported to be the first plant in the U. S. designed exclusively for the high-rate activated sludge process, uses retractable swing diffusers. Sludge digestion and sludge storage tanks are of pre-

stressed concrete. Sludge gas is stored in a low-pressure, fabric seal, Wiggins gas holder. The power plant uses six 1,300-b.hp., dual-fuel, supercharged engines. Four 15,000-c.f.m. centrifugal blowers driven by variable-speed motors of 700 hp. furnish air. The Port Richmond plant (111) provides intermediate treatment. The Hunts Point plant (25) is a conventional step aeration activated sludge plant, and the Rockaway plant (103) is also of the high-rate activated sludge type.

Kaehrle (64) presents details of the dual-fuel engine-generator and blower units installed at the new sewage treatment works of Nassau County, N. Y. Keefer (67) discusses the improvements at the Baltimore Back River works carried out during the period 1930–1947 at an expenditure of almost $4,000,000. Equipment details, design data, and a cost breakdown are given.

A valuable summary and comparison of constant-speed, multi-speed, and adjustable-speed motor drives for sewage pumps, of interest to those concerned with the selection and performance of motor drives, is presented by Potthoff (91). Carter and Karassik (19)(20) discuss basic factors in centrifugal pump inquiry and application.

Experiences, operation problems, and results with sludge heat exchangers in operation at Columbus, Dayton, and Akron, Ohio, are discussed by Blodgett (13), Calihan (18), and Long (75). Initial operating problems have been overcome and, in general, results are reported to be satisfactory. No sludge caking has been experienced.

Coberly (23) describes and shows detail drawings of a shallow circular clarifier 42 ft. in diameter and 4 ft. deep, designed for a settling rate of 0.001 ft. per sec. for peak flows of 1.45 c.f.s. Suspended solids removals of 60 to 70 per cent are reported, with 52 per cent removal at 30 per cent overload.

Design and construction details of a "scoop" type automatic waste sampling device are presented by Gard and Snavely (41). An ingenious piece of laboratory equipment to be used as the equivalent to a conventional trickling filter is described by Gloyna *et al.* (42). The equipment consists of a series of rotating plastic tubes, 24 in. long and 2¼ in. in diameter, inclined slightly from the horizontal. Raw wastes are fed in at the upper end and effluent drained from the lower end. The tubes rotate at a speed of 16 r.p.m. The flow-through time is varied by changing the angle of inclination. It is reported that the functional performance is close to that of equal wetted areas of conventional filters.

Detergents

Eliassen (29) briefly reviewed some of the fundamental characteristics of detergents. He pointed out that the stability of these agents has promoted household usage and at the same time has created difficulties with treatment processes, such as sedimentation.

In a summary of the literature concerning the effects of detergents on sewage purification, Lumb (76) has included reports on many phases of the problem. He believes the difficulties produced by detergents should not be overlooked and additional studies should be undertaken.

From the results of a series of laboratory experiments, Gaillard (40) concluded that mere addition of detergent to sewage does not influence the quality of settled sewage. However, an additional load may be imposed upon biological units by use of certain household detergents in place of soap. A portion of the surface-active material will be carried into the digesters with the settled sludge. Some agents, in concentrations above 50 p.p.m., may cause major difficulties in the operation of activated sludge units.

Manganelli (79) emphasized the point that the effect of detergents on treatment processes depends upon the concentration and type present in sewage. In general, the more widely used agents—anionic and nonionic types—in concentrations expected to be found

in sewage do not appreciably interfere with the oxidation of sewage alone or by activated sludge. However, the cationic type, used for specialized purposes, retards these oxidations. Displacement of soap by detergents diminishes gas yields from anaerobic sludge digestion without retardation of digestion processes. Anionic and nonionic detergents interfere with chemical coagulation of sewage, but an increase in the dosage of coagulant can alleviate some of the adverse effects. Cationic agents lower the quantities of coagulant required. Cationic detergents markedly decrease the number of coliform organisms during sewage sedimentation and produce an added effect to the bactericidal activity of chlorine. The anionic and nonionic types exhibit no measurable effect in either case. Aeration efficiency in activated sludge units may be impaired by surface-active compounds.

In a laboratory study, Fuller (39) found no evidence that household detergents in concentrations of 100 p.p.m. would impair the proper functioning of septic tanks. Industrial detergents seemed more likely to be detrimental, but not to a marked degree.

Hurley (59) conducted large-scale experiments at Coven Heath and Barnhurst sewage works to determine the effect of Teepol (secondary alkyl sulfate) on sewage treatment processes. He noted that Teepol concentrations up to 206 p.p.m. (20 per cent active matter) caused no operational troubles at the Coven Heath plant, and had no visible effect on the trickling filters or on the appearance of the subsurface filtering medium or on the receiving stream. Similar results were obtained with 100 p.p.m. Teepol when the load applied to the filters was doubled. After five months, ponding of the filters began, because of overloading only and not due to the presence of the detergent. Depth samples taken from the trickling filters showed that under normal loading almost all the Teepol disappeared in the top 1-ft. section, whereas under overloading the same state of removal was not reached until sewage had passed halfway through the bed. At the Barnhurst plant, which employs the Haworth bio-aeration type activated sludge process, experiments showed that concentrations of Teepol up to 125 p.p.m. had no appreciable effect on the quality of the effluent. There was no noticeable difference in the amount of frothing normally obtained.

Keefer (68), using the colorimetric method of Jones, estimated the detergent content of raw and treated sewage at the Back River plant over a 5-day period. The raw sewage contained 1.7 p.p.m. detergent on the basis of a sulfonated agent with a molecular weight of 300. Primary settling removed more than 14 per cent of the detergent, sedimentation and trickling filter treatment removed 39 per cent, whereas sedimentation and activated sludge units removed 21 per cent of the agent. The author regards more extensive analyses necessary for drawing satisfactory conclusions as to the detergent removals by various treatment devices. Considerable frothing occurred in the activated sludge units.

Lewis and Herndon (74) studied two methods for determination of anionic detergents in industrial wastes and polluted waters. A two-phase titration procedure was found more suitable than that of turbidimetric measurement. Titration is carried out by adding standardized solution of cationic agent to the two-phase system—water plus detergent phase and the chloroform phase—in the presence of acid or basic dyestuffs. The equivalence point is indicated by transfer of dye color to the chloroform layer when using acid dye or to the water layer with a basic dyestuff. Techniques for diminishing difficulties due to emulsification, presence of soap, and low concentration of agent are described. Further work for evaluation of the reliability of this method is suggested.

Heatley and Page (51) outlined a procedure for the estimation of non-

ionic detergents of the polyglycol type (Lissapol N) in sewage. Concentration of the detergent was effected by organic solvent extraction of the agent from sewage. The residue of ether extracts was taken up in ethanol plus water and precipitated with phosphomolybdic acid and barium chloride. The precipitate was subsequently dissolved in a mixture of one volume of 5N HCl plus four volumes of methyl cellosolve and the absorption at 310 mμ. was measured in spectrophotometer.

Ultrasonics

Lethal properties of ultrasonic waves were studied by Horton, Horwood, and Phinney (58). Effect of temperature, time of exposure, surface tension, and turbidity were found to be important factors in the destruction of organisms by sonic waves.

Husmann (60) found that treatment of raw sewage with ultrasonic waves resulted in a reduction of settleable solids due to the disintegration of colloidal particles, which do not settle in a reasonable time. The strength of sewage as measured by permanganate consumption increased materially. The dewaterability of fresh solids and digested sludge was not increased. Activated sludge lost its settleability and became finely divided.

Sewage Reclamation

A study of the reclamation of sewage by percolation through soil was made by Greenberg and Gotaas (44). The experiments were made on sandy-loam soil using activated sludge effluent of the Lodi, Calif., treatment plant. It was found that a ground water passing the U.S.P.H.S. bacteriological standards could be produced by percolation through the soil. Percolation rates of about 0.1 ft. per day could be maintained if the filtration areas were allowed to rest about one-half the time. Warrington (126) reports the effects of using lagooned sewage effluent on the growing of cotton. It was found that a 12.5 per cent increase in production resulted from irrigation with lagoon effluent instead of river water. This increase was attributed to an approximate 11 per cent increase in nitrogen, phosphorus, and potash in the soil receiving lagoon effluent and also to the fact that lagoon effluent was more readily available.

Stone, Gotaas, and Bacon (114) discuss the economic and technical status of water reclamation from sewage and industrial wastes. The authors have contributed a valuable survey of the problem and have presented an extensive bibliography. Data showing the mineral characteristics of reclaimed sewage after percolation through the ground are of particular interest.

Miscellaneous

MacKenzie (77) presented a good summary of the research studies on household sewage disposal systems by the U. S. Public Health Service at Cincinnati. It was found that the shape of septic tanks had little influence on their performance, although divided tanks were slightly better than single compartment tanks. The work involved in making percolation tests can be considerably reduced by boring 4-in. diameter holes instead of digging the 1-ft. square holes used in the standard test. There was little difference on the performance of absorption systems receiving soaps as against detergents, although under certain conditions with grease suspensions detergents gave less clogging.

The problem of paint protection of sewage works structures is thoroughly discussed by McClenahan (80). The usefulness of almost every type of paint and protective coating is described and the experience of the Sanitary District of Chicago is excellently used to illustrate the points made. The formulas for many protective coatings and the best methods of application are given. This article is of great value to both the plant operator and the designing engineer.

Simpson (99) reviews the problem

concerning the effect of ground garbage on sewers and sewage treatment. His conclusions are similar to those of other investigators and show that ground garbage from an entire community can be conveyed without difficulty in properly designed sewers and that a 50 per cent increase in B.O.D. and suspended solids can be expected.

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RADIOACTIVITY

General

In reviewing the present status of work with wastes of the atomic energy industry, Hayner (16) indicated that the usual techniques for the reclamation of dusts and settling of waste wa-

ters were adequate for the mining and processing of uranium ore. However, since a small amount of the highly radioactive liquid produces tolerance limits of radiation, the process wastes of reactors were being concentrated and stored. Research on improvement of separation and concentration processes is under way, but much more work is needed.

Gorman (14) discussed the possible effects of industrial and military uses of atomic energy upon water utilities. The need for waterworks officials to have an understanding of this new industry and its products in order to help solve the problems of water supply and waste disposal was stressed.

Aebersold and Rupp (1) reported that more than 20,000 shipments of radioisotopes had been made. During the two months of August and September, 1951, a total of over 70 curies of I^{131}, 18 curies of P^{32}, 0.6 curies of C^{14}, and nearly 120 curies of Co^{60} had been distributed. In recent years, the number of shipments has increased by over 1,600 each year (24). Kittrell (24) described the allocation and visitation program of the Atomic Energy Commission for the control of potential radiation hazards from isotopes distributed by AEC.

Morton (30) discussed the roll of engineering in nuclear energy development from the standpoint of health problems, the significance of environmental control, and the essentials of waste disposal and control measures to prevent radioactive contamination of water supplies (31).

Dealing, in general, with highly radioactive process waste, Eister (9) considered the following aspects of radioactive waste treatment and disposal: (a) the objective of waste control, (b) the characteristics and types of radioactive wastes, (c) the procedures for control of radioactive wastes, and (d) the processes used for waste concentration and final disposal.

Pitzer (37) and Simon (40) discussed problems in the disposal of radioactive wastes. The latter reported on the treatment and disposal of liquid and solid wastes from the laboratories, shops, and pilot plants of the Knolls Atomic Power Laboratory. Because of the heavily populated area near the laboratory, "no detectable activity" is allowed to be discharged to the ground water or to the river. After treatment, the liquid effluent is potable from the standpoint of radioactive content.

In a review on the effect of radioactive materials on environmental health, Straub (42) explained the calculation of a maximum permissible concentration and listed tentative maximum permissible concentrations of 32 isotopes when present in water or in air. Tentative maximum permissible concentrations may also be found in a progress report (34). The disposal of I^{131} by sewage treatment, dilution in streams, removal by water treatment processes, and the normal radioactive decay was considered in some detail.

In streams receiving wastes originating from naturally occurring radioactive materials, operating nuclear reactors, hospitals, research organizations, industrial areas, or an atomic explosion, the radioactivity levels should be determined on water, sediment, aquatic life, and immersed objects, according to Kochtitzky and Placak (25). Continuous monitoring for gross counts with counting instruments discriminating between types of radiation is desirable. Concentrating the sample before examination is necessary for dilute contamination.

Background Radioactivity

The natural or background radioactivity of the environment (air, water, soil, vegetation, and animal tissues) and the determination of background levels was reviewed by Healy (17). Measurements on the natural radioisotopes were considered of value where gross determinations are used to estimate trends of extraneous activity and where wastes from AEC or other installations contain the natural isotopes. Radioactive

background values for radon, thoron, uranium, potassium, and carbon for the environs and procedures for measurement were given. A rapid simple method for determining the radon content of water was presented by Thorburn and Healy (46). The method consists of treating 1 l. of water with 20 mg. of $PbNO_3$, 10 ml. of ammonium sulfide reagent, and 0.1 g. of filter aid. The treated sample is filtered rapidly, dried with acetone and air, and counted for beta activity, all within approximately 15 min.

Radium analyses of 33 municipal water supplies, representing about 20 per cent of the population of the United States, were reported by Blair (2).

The gross beta activity of uncontaminated spring water in the White Oak Creek area of Oak Ridge, Tenn., was reported (34) to be 25 $\mu\mu$c. per liter.

Wilkening (51) described an apparatus for monitoring the natural radioactivity of particulate matter in the atmosphere. The apparatus consists of an electrostatic precipitator, through which air is drawn by an exhaust blower at an estimated rate of 0.03 cu. m. per min. Particulate matter (0.001 to 0.5 microns in diameter) is deposited on a moving aluminum tape that travels into a scintillation counter where the alpha activity is detected and recorded.

Contamination

A final report on an investigation of the uptake of I^{131} from solution by metallic materials commonly used in drain systems was presented by Talboys (43). Potential hazards resulting from disposal of I^{131} to drains were computed from the experimental results. The investigators indicate that special care should be exercised to avoid contaminating exterior surfaces. Retention, however, of I^{131} by the interior surfaces of plumbing is not likely to reach hazardous proportions if very strong wastes are sufficiently diluted before disposal and if active solutions are quickly and thoroughly flushed out of the system.

The Health Physics Division of ORNL (34) reported the level of radioactivity in bottom deposits and water samples from White Oak Creek and the Clinch and Tennessee Rivers.

Studies (7) made on plankton collections from the Columbia River below the Hanford works, showed that in the period February 1949 to February 1950 the maximum radioactive density of plankton, which occurred in January, was 7.9 μc. per kg. of wet weight. The maximum plankton concentration of 1,200 p.p.m. in the river water occurred in May. The maximum radioactivity in the plankton carried by the river past Hanford occurred in July and was estimated to be 0.6 curies per day. Decay curves indicated that 5 to 30 per cent of the plankton radioactivity was from isotopes with half lives near or longer than that of P^{32}. A small proportion of the plankton radioactivity persists after 600 days.

Tracer Studies

Montens (29) reported that the half life of Br^{28} in the form of NH_4Br is long enough for practical measurements of water flow and yet short enough so that the water will not be injurious to users after several days. Safe means of transporting the isotope were discussed and an apparatus was described for measuring the activity of the water to which Br^{28} had been added. The tracer technique was considered especially useful for studying the flow in sewage treatment plants, sludge flow in pipes, etc. Fox (12) explained how radioactive rubidium chloride was used in tracing the flow of underground water in Egypt's western desert.

Waste Treatment and Disposal

A number of studies have been made on the removal of radioactive isotopes from water. Straub (41)(42) summarized pertinent research of the section relative to the treatment of radioactive wastes by evaporation, carrier

precipitation (coagulation), ion exchange by natural clays and synthetic resins, sand filtrations, etc. Although alum or iron coagulation in the presence of natural turbidity or chemical precipitation with phosphate at a pH of about 11.5 was effective in removing 85 to over 99.5 per cent of many isotopes, the removal of other isotopes, such as I^{131}, Sr^{89}, W^{165}, mixed fission products, and the radioactivity of a process waste, was much more difficult. In several cases the rather stringent treatment removed less than 50 per cent of the radioactivity.

The removal of radioactive material from contaminated water with powdered metals (Fe, Al, Cu, and Zn) was studied by Lacey (27). Oak Ridge tap water (pH 8.0) was contaminated with various radioactive isotopes, and then treated with metal dusts to give concentrations of 100, 500, 1,000, and 2,000 p.p.m. The mixtures were stirred to keep the metal dust in suspension. Depending on the isotope and its daughter, if any, it was found that from 10 to 99.9 per cent of radioactivity was removed by 1,000 p.p.m. of metal powder in 90-min. contact. The removal was least for cesium (10 per cent) and iodides (23 to 46 per cent). The removal was greatest for cerium (99.5 to 99.9 per cent), zirconium (96.9 to 99.8 per cent), and ruthenium (92.8 to 99.6 per cent). The removal of mixed fission products, phosphates, barium, and yttrium varied from 65.7 to 95 per cent. The Health Physics Division of ORNL (34) also reported on methods for removing Cs^{137}, Cd^{115}, and I^{131} from liquid waste, and the use of the lime-soda softening process for removing Sr^{90} from water.

Kaufman *et al.* (22) studied effectiveness of conventional water treatment processes for removing radioisotopic contaminants. Coagulation jar tests and pilot-plant studies were limited to the removal of P^{32} as the orthophosphate and I^{131} as the iodide. The direct adsorptive capacity of clean filter sand was found to be negligible. The removal of iodide was not successful by any of the conventional water coagulation processes.

Ruchhoft, Gorman, and Christenson (38) discussed the problem of treating radioactive wastes at Los Alamos. One of the wastes was described as having total solids ranging from 230 to more than 8,000 p.p.m., and an alpha activity of 200 to 25,000 counts per minute per liter (0.003 to 0.3 p.p.m.). This waste was treated by chemical coagulation (iron and lime to pH 12), sedimentation, and filtration to produce an effluent meeting the alpha activity standard of 70 c.p.m. per liter. The over-all plant treatment costs were given as about $0.008 per gallon. Some wastes which were not amenable to coagulation were first treated on a trickling filter. The trickling filter effluent was then further treated as a combined waste by chemical coagulation.

According to Hirsch (18), some waste solutions from the Hanford works are now reduced to one-fourth the original volume by semi-batch evaporation before storage in underground tanks as a sludge having a dry solids content of approximately 41.8 per cent and a specific gravity of 1.38. Foaming, deentrainment, sludge crystallization, and control of the evaporation process were discussed briefly. The average steam consumption was 1.21 lb. per pound of waste solution condensate. The cost per gallon of waste solution treated was $0.05 as compared to $0.37 per gallon for underground waste solution storage.

In a progress report from the Brookhaven National Laboratory (4), continued studies were made on fission product utilization and concentration, permanent radioactive waste disposal, radioisotopes separation, etc. Simon and Ginell (39) used montmorillonite-type clays for the permanent disposal of radioactive fission product waste. The radioactive elements are introduced into the clay by cation exchange. The clay is then sintered in a muffle furnace or with a torch. Clay vitrified at 900° C. and then ground, was found

to release more radioactivity when leached in sea water for 6 months to 1 year than underground vitrified clay of similar particle size. Laboratory and sewage plant studies on the efficiency of intermittent sand filters were reported by Gemmell (13). Weak domestic sewage having a yearly average flow of 0.233 m.g.d. was treated in a plant consisting of an Imhoff tank, six 6-ft. deep 1-acre filters, and a chlorine dosing tank. Infiltration to beds during the wet season amounts to as much as the sewage plant flow. The efficiency of one filter was studied by dosing it with a single batch of 25,000 gal. of sewage containing approximately 10 mc. of P^{32}, I^{131}, Sr^{90}, or mixed fission product, or 52 mc. of Pile Canal water. The filter was then dosed with sewage having very little radioactivity at a rate of 200,000 g.p.d. The fraction of added radioactivity that was recovered in the filter effluent was estimated to be 1, 2, 8, 12, and 53 per cent for Sr^{90}, P^{32}, I^{131}, and canal water, respectively. The highest concentration of activity in the effluent was obtained almost immediately after applying the radioactive dose, except in the case of P^{32}. The effluent activity then decreased and reached a background level in 3 days. When the sand filter was dosed with P^{32} the effluent activity reached a peak 24 hr. after the dose was applied. The activity then decreased gradually, but did not reach the background level until about the fifth day. An unknown amount of activity was lost due to underground seepage. The loss of flow, however, was estimated to be less than 30 per cent of the influent flow.

An analysis of the sand from different depths of the bed was made by leaching it with acid. The results indicated that 87 to 98 per cent of the leachable activity was recovered from the top 3-in. depth and only 2 to 7 per cent was recovered from the remaining depth of more than 5 ft. It was concluded that pure sand removes very little radioactivity, whereas the clay, organic matter, and bacteria present in the top few inches of a sand bed are primarily responsible for removing radioactivity.

Laboratory columns 5.6 cm. in diameter and containing 109 cm. of sand depth were dosed 4 times daily for two weeks with 300 ml. (0.38 m.g.d. per acre) of sewage containing added radioactivity. The daily dose was relatively constant for a period of one week or more. The doses selected were 0.56 and 600 μc. of mixed fission product, 83 μc. for I^{131}, and <57 to 650 μc. for P^{32}. The removal of activity was usually greater than 90 per cent for the first few days, but then decreased erratically. After a week to 10 days the removal of mixed fission product was in the order of 20 per cent for the lower dosage and 40 per cent for the higher dosage. Apparently the I^{131} and P^{32} were relatively free of stable isotope, because more than 50 per cent of the added dose was usually removed toward the end of the experiment.

Studies on the removal of P^{32} by the activated sludge process were reported by Kaufman *et al.* (21). The effectiveness of the process depended on the B.O.D. loading, the stable phosphate concentration, and the aeration period. In the course of treating a normal domestic sewage in the conventional treatment plant a high reduction of P^{32} may not be expected. Removals as high as 98 per cent of the P^{32} were possible at stable phosphorus levels of approximately 1 p.p.m. However, at stable phosphorus concentrations of 6 p.p.m. or higher, the P^{32} removals were found to be 20 per cent or less.

A resin exchange column was developed (47) to absorb and concentrate the activity of dilute low-level acidic solutions so as to permit the safe and efficient disposal of radioactive laboratory waste solutions.

Emergency Decontamination

The Federal Civil Defense Administration prepared a manual (11) on radiological decontamination which is particularly useful to radiological de-

fense personnel because it can "serve as an operational manual for decontamination crews."

The first Kellex prototype waste disposal unit for the emergency decontamination of drinking water was completed and tested (23). The efficiency of the unit was determined by feeding the ion exchanger cartridge with as much as 10 mc. of unseparated fission products in solution. The results are tabulated and include data on the performance of the filter when individual radioisotopes are tested.

Studies were made on the use of cation exchanger resins (48)(49) dyed with acid-base indicators, which would warn of the approach of conditions under which active, volatile, acidic materials would appear in the effluent. An evaluation was made of specially prepared cationic resins for the removal of radioactive material from natural waters by a mixed-bed ion exchange unit. The resin mixtures tested included the iron, aluminum, or magnesium form of HCR mixed with HCR–H (cationic) and SAR–OH (anionic). Some of these special resin beds had three times as much capacity for removing radioactivity as the conventional mixed-bed resin.

Specifications were given for the construction of a production-type incinerator for contaminated combustible liquids (26). Experiments with various inorganic reducing agents were made in an attempt to retard the conversion of the ruthenium to the volatile form and the effects of operating pressure and still-pot acid concentration on the decontamination factor were shown.

The radioactivity induced in foods by an atomic bomb explosion at a distance of 1,700 ft. was calculated (36) to be so low that the ingestion of any reasonable amount would give an insignificant radiation dose compared to presently accepted tolerance doses. No account was taken of surface contamination with radioactive material. It was claimed that surface contamination would not affect packaged food if care was used in opening the containers.

Methods and Instrumentation

The Subcommittee on Monitoring Methods and Instruments (32) of the National Committee on Radiation Protection prepared a 33-page condensed handbook containing chapters on radiation hazards, radiation detectors, measuring instruments, personnel monitoring instruments, instrument requirements, radiation survey methods, and air and water sampling techniques for alpha and beta counting.

Four methods of assaying the radioactive contamination of water were suggested by a task group of the American Water Works Association (44). The methods vary from simple procedures and inexpensive instruments suitable for assaying emergency permissible levels of contamination to more involved and expensive procedures and instruments suitable for measuring levels of activity slightly more than the natural background radioactivity of water. Several of the techniques suggested by the Task Group were tested at ORNL (35). It was found that G–M survey meters used in monitoring 0.15 to 7 l. of water would detect 0.1 to 100 μc. of fission products per liter of water, depending on the particular meter and size of sample. The Landsverk and Lauritzen electroscopes had comparable ranges of sensitivity. When 500 ml. of liquid sample were tested with an electroscope, the efficiency of detection was much less than the survey meter techniques. When samples were evaporated and the solids dried on planchets before reading with an electroscope, the alpha, beta, and gamma radiation was detectable at an activity as low as 1, 100, and approximately 10,000 $\mu\mu$c., respectively. Assuming 1 l. was evaporated, the beta activity would then be detectable at near the maximum (lifetime) permissible level.

Bruner and Perkinson (5) compared the relative effectiveness of 9 counters for detecting I^{131} in liquid or dry sam-

ples from a standard solution containing 15.7 μc. I^{131} per liter. The gas-flow proportional counter, the mica end-window G–M counter, and the quartz-fiber electroscope were listed as the most sensitive and efficient of the counters tested by a specific dry sample technique. The minimum detectable activity (given as a value equal to the background of the instrument) was found to be 80 $\mu\mu$c. for proportional counting, 110 to 330 $\mu\mu$c. for end-window counting, and 800 to 900 $\mu\mu$c. for readings on an electroscope, as against values of 1,000 to 100,000 $\mu\mu$c. when liquid samples were counted.

A low-level monitor for radioactive contaminants such as mixed fission products in water was developed by Emmons and Lauderdale (10). The unit consists of a 10-in. glass G–M tube imbedded in a column of high-capacity, strong, acid-type resin exchanger. As contaminated water is passed through the column at a constant rate, the counting rate increases in proportion to the contamination level. Although the counting efficiency of the unit is in the order of 1.5 per cent, it is a simple method of continuously monitoring contaminated water of low ionic strength at levels above about 300 μc. per liter.

Two devices were described by Hurst (19) for continuously monitoring drinking water for alpha-beta-gamma radioactivity. One device is a continuous-flow water cell with a radiation detector. The other is an instrument for calibrating the water cell and detector response. The latter instrument also can be used to measure the activity of liquid samples. A Geiger counter is surrounded by, but not in contact with, a rapidly rotating cylindrical wall of water of 1-cm. radial thickness. The K^{40} naturally present in body fluids of the human being can be detected easily. The Sr^{89} and Tl^{204} activity in water can be detected at a concentration of 1,000 and 3,000 $\mu\mu$c. per l., respectively. Alpha radiation (from Pu^{239}) can be detected at 40,000 $\mu\mu$c. per l. Operation for 1 hr. with a solution having a Sr^{90} activity of 100 μc. per l. resulted in no measurable contamination of the counter tube.

Thompson (45) developed a 4-pi proportional beta counter, which permits more reliable measurements to be made, particularly when a minimum amount of information about the decay scheme of the radioactive material is available.

Blüh and Terentiuk (3) investigated the use of liquid phosphors for counting the beta activity (K^{40}, S^{35}, and C^{14}) of solid samples. Thin deposits of sample were mounted on transparent foil. The counting efficiency depended on the technique of sample preparation, but it could be maintained at greater than 10 per cent. Activities in the order of 1 μc. per kilogram of solids could be measured.

Since the naturally occurring potassium gives off 28.3 $\pm$1.0 beta particles per gram per second, and the concentration of potassium per gram of urine solids varies, Cowan and Weiss (8) proposed improving the radioassay of urine by precipitating the potassium with cobaltinitrite, evaporating 100 ml. of filtrate, mounting the dried sample on a flat planchet, and counting with a thin-window G–M tube.

Chang and Cook (6) described a method used to determine the relative transmission of weak beta particles through a G–M window having a window thickness of 7.32 mg. aluminum per square centimeter. About 30 per cent of beta particles with an energy of 0.1 M.e.v. and 70 per cent of beta particles with an energy of 0.2 M.e.v. were transmitted into the counter.

The effect of thickness of beta-active samples on the counting rate of an end-window counter was studied by Nervik and Stevenson (33). It was found that radiation scattered into the counter predominates at low thickness and self-absorption increases with thickness.

Mazza (28) used a simple technique for separating various rare-earth mixtures. The separations were made by permitting the eluate from an ion-exchange column to flow into a gently

sloping tube, to which were attached a series of flasks, each being filled in order. As each flask was filled, the hydrostatic pressure prevented mixing of its contents with the eluate stream. Separations achieved with various rare-earth mixtures were shown by graphs.

Harley and Foti (15) described a method whereby micromicrogram quantities of radium in 200 ml. of water or urine were determined by co-precipitation of the radium in three steps with Ba^{++} and SO_4^{--}. The alpha activity from Ra^{226}, Rn^{222}, Po^{218}, and Po^{214} was counted at a subsequent date when equilibrium with daughter elements had been established or was known.

The radium in residues containing silica, Ba and Pb sulfates, and other oxides and sulfates was determined by Wamser *et al.* (50) by heating the sample in a platinum vessel with H_3PO_4 and HF. The viscous melt, free of Si, HF, and sulfate, was soluble in water. The radium in solution may then be determined in an appropriate aliquot by the standard $BaCl_2$ carrier precipitation procedure.

The density of photographic film exposed to beta radiation from uranium was correlated with an air ionization measurement (20). A dose of 3 r.e.p. corresponded to a film density of 1.25 or 1.75, depending on the type of film. Although the film is energy-dependent, within the energy range studied (0.5 to 1.4 M.e.v.) the film ionization is roughly proportional to beta ionization in air. At low-dose rates from beta radiation transmitted through the equivalent of about 5 m. of air, the film exposure reading would be low (3.2 m.r.e.p. per hr., as compared to an air ionization reading of 4.3 m.r.e.p. per hr.). This discrepancy was considered of low practical significance, since the exposure level is a fraction of the allowable exposure.

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The second and concluding section of the "1952 Literature Review," covering references to industrial wastes and stream pollution, will be published in the June, 1953, issue of THIS JOURNAL.

INTERIM REPORT ON ACTIVITIES OF THE JOINT COMMITTEE ON CHLORINE SUPPLIES

During 1952 and the first quarter of 1953 the Joint Committee on Chlorine Supplies has been active in trying to find reasonable solutions to several questions on chlorine which have caused concern and irritation in the past at some water and sewage treatment plants. It was agreed by the Committee members to set forth their recommendations in a statement or report entitled "The Reasonable Use of Chlorine at Water and Sewage Plants." The report will cover the following subject material:

1. Conditions of use for chlorine cylinders and ton containers.
2. Minimum and maximum chlorine inventories at water and sewage treatment plants.
3. Transportation of liquid chlorine.
4. Policy and practices in return of empty containers to chlorine suppliers.
5. Safety in the use and handling of chlorine.
6. Stand-by chlorination equipment.
7. Stationary (static) storage of liquid chlorine.
8. Procedure to be followed to secure chlorine in the case of an emergency.
9. List of known manufacturers of chlorinators and equipment for feeding hypochlorites.
10. List of liquid chlorine producers and repackagers in the U. S., Canada, and Cuba.
11. List of manufacturers of dry hypochlorites.

The first draft of the report has been prepared and has been sent to experts in the field for comment and suggestions. It is expected that a semi-final draft will be prepared by the middle of June, 1953. The final draft should follow in two months.

The Committee hopes that the report will tend to standardize or crystalize the thinking of plant operators, consulting engineers, public health engineers, and chlorine manufacturers on the subject discussed, especially with regard to items 1, 2, 4, 6, and 8.

The membership of the Joint Committee includes representatives from the Conference of State Sanitary Engineers, the Federation of Sewage and Industrial Wastes Associations, the American Water Works Association, and the U. S. Public Health Service.

Sewage Works

REMOVAL OF PHOSPHORUS FROM SEWAGE PLANT EFFLUENT WITH LIME

By Richard Owen

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During the past few years, an increasing amount of attention has been directed toward nuisances associated with development of undesirable algal growths in lakes and ponds. Chemical treatment with copper sulfate has been used for temporary control of algal nuisance, but the expense, except for limited areas, is frequently prohibitive.

Reports on studies conducted at Madison, Wis. (1)(2), have indicated that (a) a high inorganic phosphorus and nitrogen concentration is often a major cause of the growth of these algae; (b) sewage treatment plant effluents that are discharged to a confined body of water, such as a lake, may contribute a considerable portion of the total fertility; (c) lakes having high phosphorus and nitrogen concentrations usually are affected by algal blooms; (d) nitrogen can become available from fixation by plankton growths already present in the water; and (e) the removal of phosphorus from effluents entering the lake should control one of the basic causes of objectionable algal blooms.

Although the significance of phosphorus in the production of blooms has been established only by circumstantial evidence, it seemed worthwhile to investigate the amount of phosphorus which would normally be found in a raw sewage, and to determine the removal to be expected by normal sewage treatment. In addition, a method of phosphorus removal has been proposed and tested on a laboratory and plant scale. The results of these investigations are discussed in this paper.

Phosphorus Content of Sewage and Removal by Treatment Processes

There is a decided lack of information in the literature pertaining to the phosphorus content of raw sewage. Rudolfs (3) states: "The amount of P_2O_5 present in domestic sewage appears to vary from 1.5 to 3.4 g. per capita per day." (This concentration range, in terms of elemental phosphorus, the basis used in this report, is 0.66 to 1.5 g. per capita per day.) Much of the data on which this information was based were obtained from the analysis of grab samples, assuming sewage flows of 100 g.p.c.d., and include the results of the analysis of samples collected both in the United States and abroad. Sawyer (4) states that estimates on current consumption of phosphorus in the formulation of synthetic detergents and water softeners indicate that the average amount of phosphorus in domestic sewage has doubled in the last six years.

The raw sewages and final effluents from the sewage treatment plants of nine communities in Minnesota were analyzed for total phosphorus during 1950 and 1951 in order to ascertain whether the figures quoted were applicable to raw sewage in Minnesota and to determine the amount of phosphorus removed by sewage treatment

plants. The samples collected were in all cases 24- or 48-hr. composites proportioned to the measured flow. The populations used for calculating the per capita phosphorus contribution were interpolated or extrapolated from 1940 and 1950 census data. The communities considered in this study varied in population from 1,200 to 940,000 (see Table I).

The results show a variation in per capita contribution from 1.5 to 3.7 g. of elemental phosphorus in the different communities. This variation is attributed to the several types and the volumes of industrial wastes present in the sewages tested. It is to be noted that the lowest value in the table, 1.5 g. per capita per day, is the same as the highest value reported by Rudolfs (3). The higher values obtained by this investigation over those obtained by Rudolfs are believed to be influenced by the increased usage during recent years of phosphorus-containing detergents.

The amount of phosphorus removed by sewage treatment plants varied from 2 to 46 per cent. Those plants with treatment units that accomplished the highest 5-day B.O.D. removals accomplished generally higher removals of phosphorus.

TABLE I.—Phosphorus Content of Raw Sewage; Per Capita Phosphorus Contribution and Removal of Phosphorus by Normal Sewage Treatment

Pop.	Type of Sewage Treatment	Phosphorus		5-Day B.O.D. Removal (%)
		Contribution (g./cap./day)	Removal by Treatment (%)	
2,600	Secondary	2.0	3.1	75
940,000	Primary	2.0	19	42
5,700	Secondary	2.4	11	83
1,700	Secondary	2.3	—	—
1,100	Secondary	2.2	46	85
1,500	Secondary	2.7	41	95
6,300	Secondary	3.2	20	90
1,200	Act. Sl.	1.5	42	94
13,500	Primary	3.7	2	24
Average		2.4	23	—
Median		2.3	20	—

Preliminary Studies

Tests conducted in the laboratory showed that phosphorus could be removed from sewage plant effluents by adding lime in controlled dosages. The added lime causes a precipitation of the phosphorus by increasing the pH of the medium. The mechanism of the reaction is not exactly known, but it is believed that the resulting increase in pH converts the mono-hydrogen ortho-phosphate present in the sewage at normal pH values into ortho-phosphate ion, which combines with calcium ion to form the very insoluble tricalcium phosphate. The floc produced probably aids the removal by adsorption of phosphorus-containing organic compounds. A sewage plant effluent that has been fully stabilized would probably contain the most ortho-phosphate form of phosphate, since this form is believed to be the most common stable oxidation state of phosphorus. A pH of 11.0 was found sufficiently high to precipitate the phosphorus.

To determine proper lime dosages for a plant-scale test, preliminary studies were conducted on a sample of the effluent of a high-rate trickling filter. The sample was initially analyzed for both total and soluble phosphorus, but in this sample, which contained a very small quantity of suspended solids, and as was found in samples of other filter effluents having a low suspended solids content, the total and soluble phosphorus concentrations were the same. All subsequent analyses of this sample for phosphorus were made using the soluble phosphorus determination.

The sample was split into five portions, to each of which was added unslaked lime (CaO) in the form of a slurry to obtain concentrations varying from 0 to 600 p.p.m. The samples were mixed simultaneously for about 1 min. The pH and the soluble phosphorus content of both the filtered and

TABLE II.—Laboratory Test; Soluble Phosphorus Concentration and pH of Supernate of Low-Rate Trickling Filter Effluent after Mixing with Various Concentrations of CaO and Settling

Sample	CaO (p.p.m.)	Immediate pH	1-Hr. Settling Time			18-Hr. Settling Time	
			Sol. Phos. Conc. (p.p.m.)		pH	Sol. Phos. Conc. (p.p.m.)	pH
			Unfilt.	Filt.		Unfilt.	
0	0	7.3	6.0	6.0	7.3	6.0	7.25
1	150	8.9	2.7	0.88	9.1	2.4	9.1
2	300	9.7	1.3	0.6	9.9	0.72	10.6
3	450	10.7	0.5	0.05	10.8	0.05	11.1
4	600	10.75	0.25	<0.01	10.95	0.015	11.3

unfiltered supernate were determined after 1 hr. and again after 18 hr. of settling.

The data are presented in Table II and Figures 1, 2, and 3. Figure 1 shows the relation between the pH and resulting soluble phosphorus concentration of the supernate. The initial soluble phosphorus concentration was 6.0 p.p.m. at a pH of 7.3. The larger the lime dose, the higher the resulting pH and the lower the concentration of soluble phosphorus in the supernate. The break in the curves occurred at about pH 10.5, after which the soluble phosphorus concentration dropped rapidly toward zero.

Figure 2, based on the same data, shows the effect of increased lime dosage on the pH. Curve A shows the theoretical pH of a pure water to which various concentrations of lime have been added, as calculated from the equilibrium constant of water.

It will be noted that 28 p.p.m. of lime would be required to raise the pH of pure water to 11.0, whereas a dosage of 400 to 600 p.p.m. (depending on the time allowed to reach equilibrium) was required to raise the pH of the sample to the same value. One reason for the great difference is that normal sewages are highly buffered by bicarbonate ion, which may occur in the natural water or be introduced by oxidation of organic matter in the sewage during the treatment process. Considerable quantities of the hydroxyl ion produced by the lime react with this bicarbonate to produce carbonate ion, and are therefore not available.

Figure 3, again using the data in Table II, shows the relation between soluble phosphorus concentration in the supernate and the amount of lime added. It is evident that the larger lime dosages produced better removals, and that for a given lime dosage the longer detention times produced better removals. Further inspection of Figure 3 shows that 320 p.p.m. lime produced a concentration of 0.5 p.p.m. soluble phosphorus after an 18-hr. settling time, and that a dosage of 600 p.p.m. lime gave a concentration of 0.15 p.p.m. after an 18-hr. settling time, and 0.25 p.p.m. after a 1-hr. settling period.

On the basis of these laboratory tests, it was decided to use 545 p.p.m. unslaked lime or 720 p.p.m. slaked lime for the plant-scale test.

Plant-Scale Test

An operating plant was selected to confirm the tests made in the laboratory. The plant was designed to treat 1 m.g.d. of sewage and to provide approximately 90 per cent removal of 5-day B.O.D. It receives primarily domestic sewage. Industrial waste is predominantly from milk plants. The units in this plant consist of fine screens, high-rate trickling filter, sec-

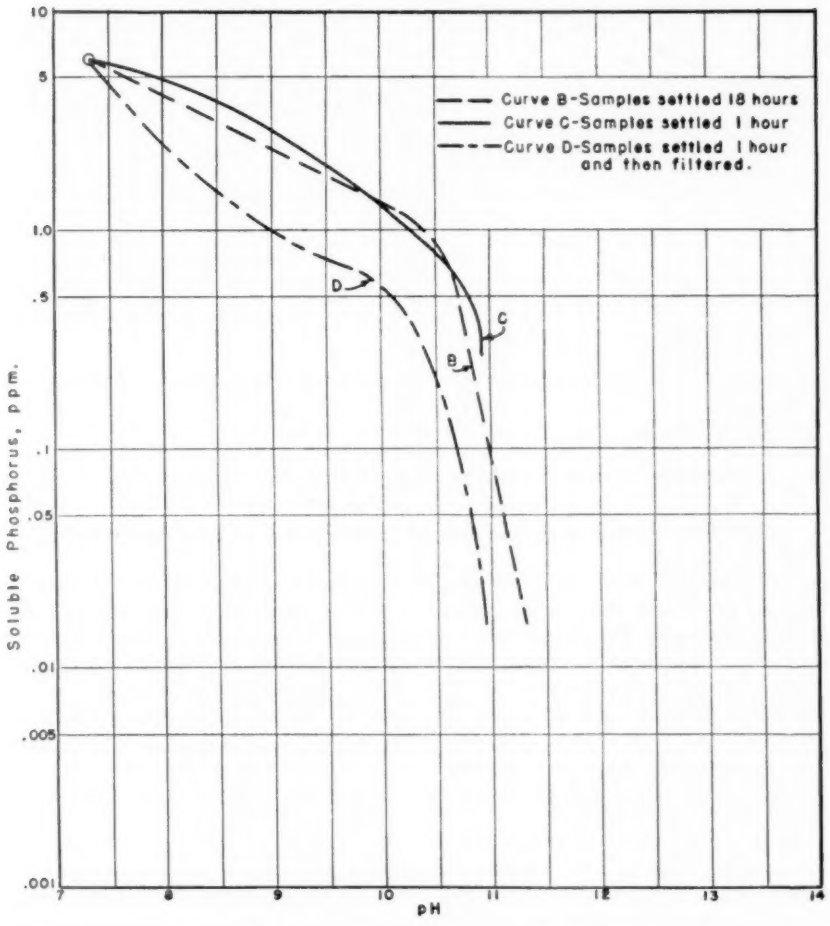

FIGURE 1.—Effect of pH on soluble phosphorus concentration in low-rate trickling filter effluent with lime added.

ondary clarifier, low-rate trickling filter, final clarifier, and facilities for vacuum filtration of sludge. During this investigation, the sewage volume was 0.70 m.g.d. or 70 per cent of full capacity of the plant. A previous investigation indicated that 83 per cent of the 5-day B.O.D. and 11 per cent of the phosphorus were being removed by ordinary treatment in this plant.

The final settling tank consisted of two tanks operating in parallel, and it was decided to add lime slurry to the inlet of one tank and use the other tank for control. Two 55-gal. drums with one end open and spigots welded to the bottom side were used to mix and apply the lime slurry. The slurry was kept in suspension by means of a centrifugal pump, which recirculated the contents of the drum at about 10 g.p.m. and also provided a means of obtaining make-up water for the lime slurry. The drum was set over the channel leading to the one settling tank. Three series of tests were made

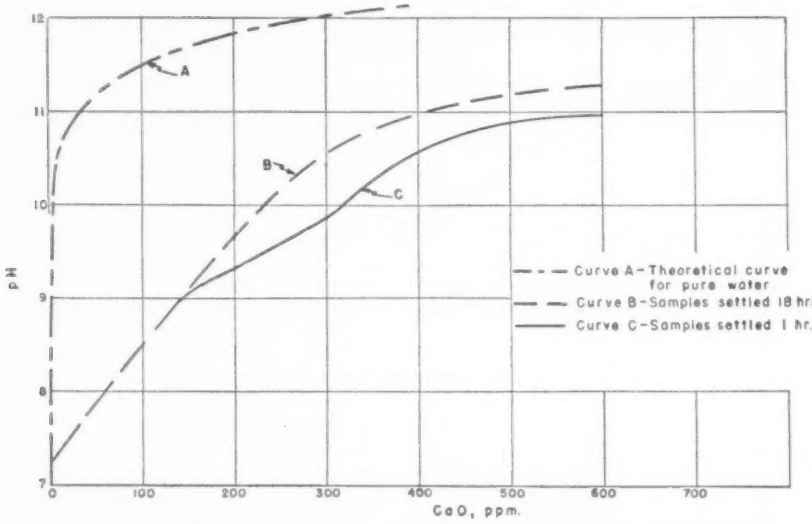

FIGURE 2.—Effect of lime addition on pH of low-rate trickling filter effluent.

on April 18–21, 1950, using variable dosages of slaked lime during three consecutive days. The dosage rate was controlled manually to maintain an average daily concentration of 720 p.p.m. $Ca(OH)_2$ on the first, and 360 p.p.m. on the second day. The third day the high-rate filter was by-passed and the lime dosage was again increased to 720 p.p.m. (see Figure 4).

Samples were collected hourly for 64 consecutive hours at the influent and effluent ends of the tank. These individual samples were bottled and returned to the laboratory for analysis. In addition, samples were collected and composited according to the flow from both the untreated and treated tanks. The rate of flow was obtained by timing the rise of raw sewage in the wet well.

A sludge sample was obtained from the sludge pump serving the final settling tank.

Results

First- and Second-Day Tests

The first- and second-day tests were made with all plant units operating and under similar flow conditions. The calculated concentrations of lime as used on these days were 720 and 360 p.p.m., respectively. The results of analysis of all the hourly samples for total phosphorus are presented in Figure 4. The composite average data are presented in Table III. On the first day there was a reduction of total phosphorus concentration from 7.4 to 1.7 p.p.m., or 77 per cent. The second day dosage of 360 p.p.m. resulted in a reduction of total phosphorus from 7.8 to 2.6 p.p.m., or 67 per cent. The soluble phosphorus concentrations on the first and second days were 4.3 and 4.2 p.p.m. for the influent, and 0.13 and 1.5 p.p.m. for the effluent, respectively. This would indicate that the higher lime dosage was considerably more effective than the lower dosage, and that a theoretical removal efficiency of 97 per cent could have been achieved with the higher dosage if all the precipitated phosphorus had settled under proper conditions of settling and with sufficient settling time.

The time of the highest total phosphorus removal obtained on these two days was between 2:00 and 4:00 AM on the first day, at which time the

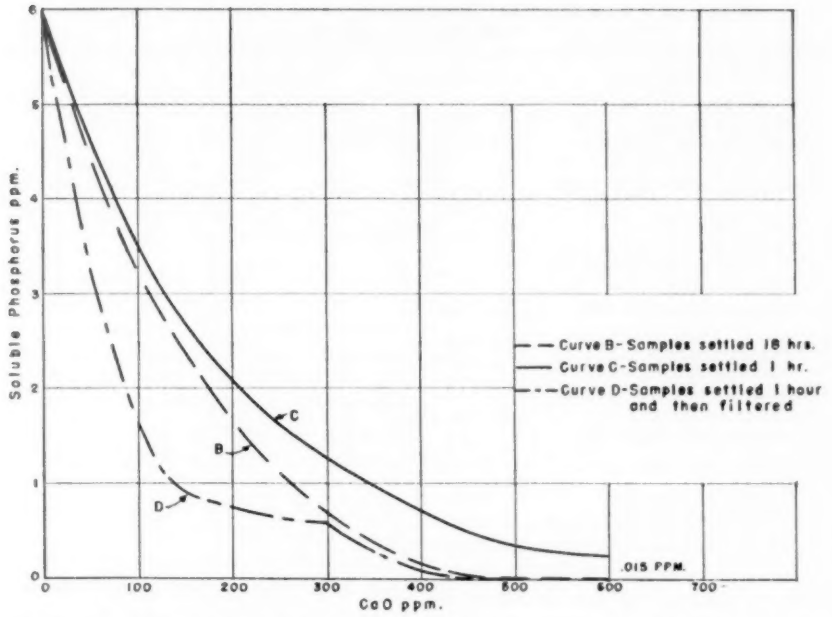

FIGURE 3.—Effect of lime addition on soluble phosphorus content of low-rate trickling filter effluent.

total phosphorus concentration entering the tank averaged 5.3 p.p.m., and that leaving the tank 0.4 p.p.m., a reduction of 93 per cent. This time roughly corresponded to the maximum retention period in the tank, which, calculated from flow data and tank capacity, was 4.2 hr.

Conversely, at 8:00 AM of the second day the minimum removal was obtained (exclusive of the first few hours of operation on the first day). At this

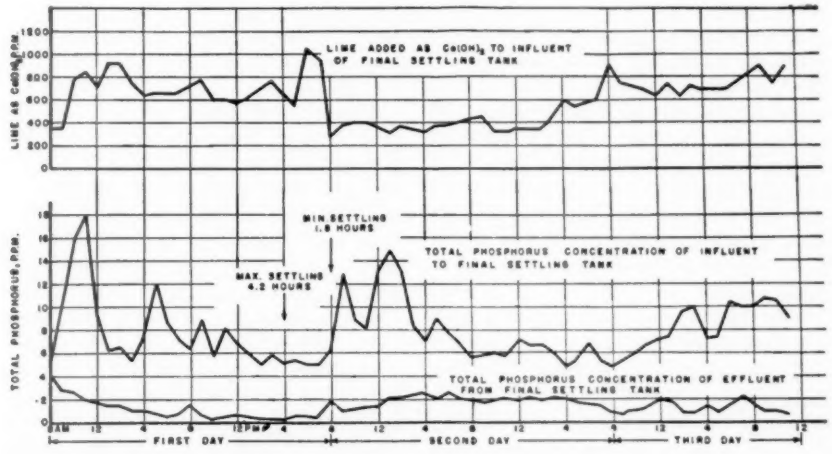
LIME ADDED AS Ca(OH)2 TO INFLUENT OF FINAL SETTLING TANK
MIN. SETTLING 1.8 HOURS
MAX. SETTLING 4.2 HOURS
TOTAL PHOSPHORUS CONCENTRATION OF INFLUENT TO FINAL SETTLING TANK
TOTAL PHOSPHORUS CONCENTRATION OF EFFLUENT FROM FINAL SETTLING TANK
TOTAL PHOSPHORUS, PPM.
FIRST DAY
SECOND DAY
THIRD DAY

FIGURE 4.—Removal of phosphorus from sewage treatment plant effluent by lime.

TABLE III.—Plant-Scale Test; Results of Experimental Removal of Phosphorus with Lime (Composites)

Item	First Day	Second Day	Third Day[1]
Total flow (g.p.d.)	693,000	698,000	513,000[2]
Slaked lime used[3] (sacks)	42	21	32
(lb.)	2,100	1,050	1,600
Lime concentration (p.p.m.)	720	360	750
Total phosphorus:			
Entering final tank (p.p.m.)	7.4	7.8	8.3
Leaving final tank (p.p.m.)	1.7	2.6	1.2
Removed (p.p.m.)	5.7	5.2	7.2
Removal efficiency (%)	77	67	86
Soluble phosphorus:			
Entering final tank (p.p.m.)	4.3	4.2	
Leaving final tank (p.p.m.)	.13	1.5	
Removed (p.p.m.)	4.17	2.7	
Removal efficiency[4] (%)	97	65	

[1] 16 hours.
[2] Gallons per 16 hr.
[3] One-half of sewage treated.
[4] Based on soluble phosphorus entering final tank.

time, 6 p.p.m. total phosphorus concentration was found in the influent to the settling tank, and 1.4 p.p.m. was found in the effluent, a reduction of 68 per cent. This time corresponded to the maximum flow at the plant and therefore to the minimum settling time in the tank (1.8 hr.) This would further indicate that the longer settling time is beneficial in that it allows a longer time for settling of the precipitated phosphates.

The average daily theoretical settling time, assuming the entire capacity of the tank to be displaced, was 2.8 hr.

An actual test of settling time was made using fluorescein as an indicator dye. The dye traversed the length of the settling tank in 20 min. when the theoretical detention time was 2.2 hr. The actual detention time was therefore somewhat lower than the calculated value.

The plant-scale test data agreed with the data from laboratory tests, which indicated that with a longer settling time (about 4 hr.) than that which occurred in the settling tank during the test, a much better removal could be obtained. It may also be pointed out that although the method of mixing the lime slurry with the sewage was the best available, it did not lend itself to good results. It is estimated that roughly 25 per cent of the lime settled directly to the sludge hopper before going into solution, and was therefore wasted.

Third-Day Test

During the third day the high-rate filter was by-passed. Other conditions were similar to those on previous days. The results are given in Figure 4 and Tables III and IV.

During this phase of the test the lime dosage was maintained at 720 p.p.m., as during the first day. Eighty-six per cent removal of phosphorus was obtained, which was slightly higher than the 77 per cent removal obtained previously. The lime treatment also was of value in removing 5-day B.O.D. and total Kjeldahl nitrogen (see Table IV). Slightly more than twice the percentage reduction of 5-day B.O.D. and total Kjeldahl nitrogen was obtained in the effluent of the treated portion of the tank than in that of the untreated portion.

TABLE IV.—Plant-Scale Test; 5-Day B.O.D. and Kjeldahl Nitrogen Removals by Lime Treatment[1]

Analysis	Infl. to Final Tank (p.p.m.)	Untreated Effl.		Treated Effl.	
		(p.p.m.)	Red. (%)	(p.p.m.)	Red. (%)
5-day B.O.D.	130	83	36	27	79
Kjeldahl nitrogen	20	17	15	13	35

[1] Lime (slaked) dosage, 720 p.p.m.; third-day test.

Sludge Disposal

Although it was not feasible to measure the quantity of sludge produced by the lime treatment during the test, results of calculations from analysis of the sludge indicated that about 6,000 to 8,000 gal. of sludge at 6.6 per cent solids would be obtained daily with lime treatment. This volume is approximately three times the volume of sludge ordinarily handled at this plant. Experiments in the laboratory have indicated that lime-treated sludge could be stored longer and would filter more easily than untreated sludge. These tests also indicated that the lime contained in the sludge was sufficient to replace the lime normally needed for vacuum filtration. The plant operator reported that considerable difficulty was encountered in filtering the limed sludge, so that he was obliged to discharge it to sand drying beds, where dewatering proceeded satisfactorily. The failures in filtering this sludge may have been due to the mixing of limed sludge with partially digested sludge in the holding tank and/or clogging of the filter cloth by the sludge. It is believed that a different filter cloth would handle this type of sludge without difficulty.

Cost of Treatment

1. Chemicals—The total chemical cost, when estimated on a basis of 720 p.p.m. slaked lime or 530 p.p.m. unslaked lime at this plant, would be $26 per day for slaked lime (at $18.80 per ton) and $21 per day for unslaked lime (at $17.80 per ton delivered).

2. Additional Equipment—In order to use the lime efficiently, additional equipment and facilities for handling the treated sewage and sludge would have to be provided over that normally encountered in a sewage treatment plant. Storage and handling equipment for lime, as well as an automatic lime feeder, would be essential. A tank for quick mixing and flocculation of the limed sewage would be necessary prior to sedimentation. Larger sludge storage and dewatering facilities would be required.

Summary

1. Analysis of samples of domestic sewage from the communities in Minnesota, with populations varying from 1,200 to 940,000, showed that the raw sewage of these communities contained (a) 1.5 to 3.7 g., with a median of 2.3 g., of phosphorus per capita per day; and (b) the amount of phosphorus removed by sewage treatment varied from 2 to 46 per cent, with an average removal of 23 per cent and a median value of removal of 20 per cent. The higher removals were found generally in plants with secondary treatment, which accomplished the highest degrees of 5-day B.O.D. reduction.

2. Laboratory studies on the sewage samples indicated that:

a) Phosphorus can be almost completely removed by adding lime in controlled dosages to an effluent after mixing and allowing the resulting precipitate to settle under quiescent conditions.

b) The dosage of lime required to

effect a pH of approximately 11.0 will almost completely precipitate the phosphate.

c) 545 p.p.m. unslaked lime (CaO) produced a pH of 10.9, and when settled for 1 hr. reduced the phosphorus concentration of the supernate from 6 p.p.m. to 0.3 p.p.m., a reduction of 95 per cent.

d) When the settling period was increased to 18 hr., the phosphorus was reduced to 0.015 p.p.m., a reduction of 99 + per cent.

3. Results of a plant-scale test conducted at a sewage treatment plant indicated that:

a) Laboratory findings were substantially confirmed. Slaked lime, when added to the influent of the final settling tank in sufficient quantity to produce a calculated concentration of 720 p.p.m. $Ca(OH)_2$ (545 p.p.m. CaO), reduced the phosphorus concentration from 7.4 p.p.m. to 1.7 p.p.m., a reduction of 77 per cent.

b) If the lime were added to the final settling tank, the volume of sludge produced would be approximately three times the volume without lime.

c) The chemical costs for year-round treatment with unslaked lime would be approximately $7,600 when treating sewage flowing at a rate of 0.5 m.g.d.

d) Although the existing plant facilities did not lend themselves readily to a full-scale trial of the true efficiency of the lime method, it is believed that the removal of phosphorus would have more closely approached the laboratory results and that the amount of chemical used could be decreased with proper mixing, efficient flocculation, and sufficient settling time.

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LAURYL TRYPTOSE BROTH FOR COLI DETERMINATIONS IN CHLORINATED SEWAGE

By C. T. Mudgett

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Studies on the effectiveness of sewage chlorination were made at the Muskegon, Mich., sewage treatment plant during the summers of 1950 and 1951 (1), using the coli count as the criterion. This determination was made according to "Standard Methods" (2), with the planting of three duplicate tubes in four dilutions in lactose broth followed by transfer of the positive tubes to brilliant-green bile for confirmation.

Before this work was started, discussions about procedures and methods indicated that samples planted directly in lauryl tryptose broth probably would give results comparable to the lactose and brilliant-green bile tests with much less time, work, glassware, and incubator space. It was decided, therefore, to run parallel samples of chlorinated effluent in lauryl tryptose whenever time and incubator space were available. Accordingly, 18 samples were run in 1950 and 76 samples were run in 1951. The comparisons drawn herein are for the 1951 season because of the greater number of samples run, although the 1950 data show like results.

The results are significant, but the number of samples necessary for confident results for bacteriological determinations is overwhelming, and the interpretation of the comparisons of these results is difficult. Every sample did not show the same results with the lauryl tryptose as with the brilliant-green bile, but Table I gives an idea of the variation.

It will be noticed that with M.P.N. values less than 100, the brilliant-green bile had the greatest number of samples. For all steps above the 100, the lauryl tryptose and brilliant-green broths show practically the same number of samples, the lactose broth not being comparable. This would indicate that the lauryl tryptose gives higher results for low concentrations of organisms. The bacteriologist, for his own satisfaction, planted samples in both brilliant-green bile and lauryl tryptose from the lactose and found that the lauryl tryptose made more confirmations, which were further confirmed on plates. In other words, brilliant-green bile was inhibitive to low concentrations of coli.

Of course, another comparison is the arithmetical averages. These are complicated by some results below the dilutions planted and, in the case of lactose, three were higher than the dilutions planted. In the averages that follow, all determinations were used and counted as the maximum or minimum recorded. The arithmetical averages for determinations by lactose, brilliant-green bile, and lauryl tryptose broth were 7,380, 510, and 870, re-

TABLE I.—Comparative Results of Coli Determinations Using Three Broths

M.P.N. Coli per 100 ml.	Number of Samples		
	Lactose Broth	Brilliant-Green Bile	Lauryl Tryptose Broth
< 100	2	41	29
< 300	3	53	51
< 500	6	63	59
< 1,000	9	70	70
< 2,500	16	70	71
< 5,000	53	76	74
<10,000	65	76	75
<50,000	76	76	76

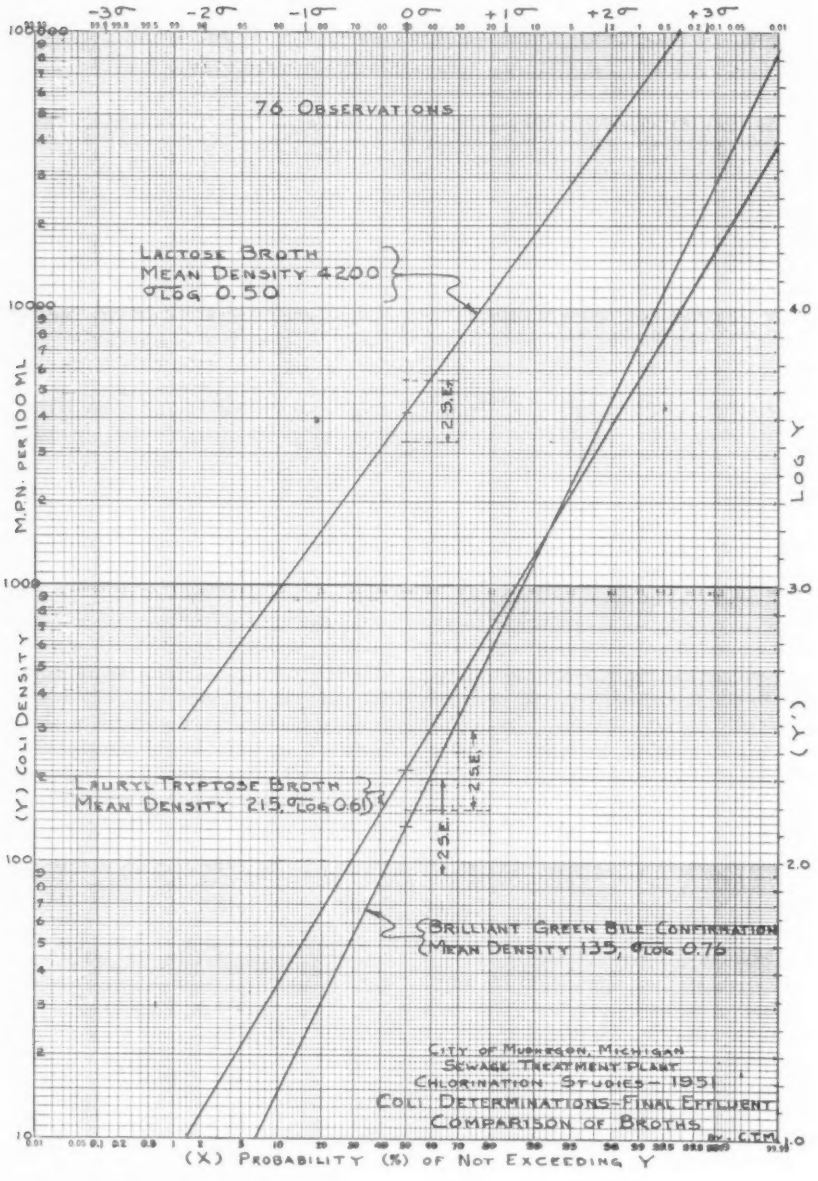

FIGURE 1.—Comparison of final effluent coli determinations using lactose broth, lauryl tryptose broth, and brilliant-green bile confirmation.

TABLE II.—Comparison of 95 Per Cent Confidence Limits for Results by Various Coli Determination Procedures

Broth	Most Probable Density	Limits of 95% Assurance of Most Probable Density Being	
		Low	High
Lactose	4,200	3,300	5,500
Brilliant-green bile	135	90	200
Lauryl tryptose	215	155	300

spectively. The lactose results were high, but with the other two broths the results were close enough to have little significance, although the brilliant-green bile results are slightly lower.

These two comparisons may be sufficient, but the statistical method (3) of plotting the results on log probability paper (Figure 1) is intriguing and the more it is studied the more meaningful it becomes.

Here again, the lactose is high and the lauryl tryptose and brilliant-green bile curves are very close together. The lower concentrations show lower results with brilliant-green bile than with lauryl tryptose, but for higher concentrations the lauryl tryptose is lower. It will also be noticed that the lactose results come closer to the brilliant-green bile in the higher concentrations. To carry the interpretation further, Table II shows that within the 95 per cent limitations there is no chance of the lactose results equalling the brilliant-green bile or lauryl tryptose results. The brilliant-green bile high, however, is well above the lauryl tryptose low. With this overlap, the statisticians state that there is no significant difference.

Conclusions

On the basis of the results given it was concluded that for chlorinated sewage effluent (a) simple lactose broth planting, presumptive test, gives high results of little coli significance; and (b) the simple planting in lauryl tryptose broth will give results comparable to the standard lactose broth test with brilliant-green bile confirmation.

If the simplified method described were accepted by the profession, it would make possible the running of the coli test in many more plants. The 1952 studies at Muskegon were made exclusively with lauryl tryptose broth. This permitted the making of twice the number of determinations with the same effort, glassware, and incubator space.

Acknowledgments

The author wishes to acknowledge the help and advice given by D. M. Pierce, of the Michigan Department of Health, and Prof. W. L. Mallmann, of Michigan State College, in carrying out and evaluating the work reported herein; and to express his thanks to Dale Bordt, graduate student, Michigan State College, for carrying out the laboratory work.

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REMOVAL OF RADIOACTIVE IODINE BY LABORATORY TRICKLING FILTERS *

By Melvin W. Carter

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Wolman and Gorman (1), in discussing the future of the atomic energy industry, state that ". . . the future growth of this new industry from the developmental stage to that of applied use of its products may well hinge on its ability to find increasingly effective and reasonably economical methods of disposal of its hazardous waste products."

The Atomic Energy Commission has recognized this problem and has initiated extensive research programs, both on and off Commission sites, to work toward a solution of its complex waste disposal problems. Ruchhoft (2) has outlined the possible use of biological treatment methods for treating radiological wastes and has given some preliminary results from the use of the activated sludge process for treatment of plutonium wastes at Los Alamos. He also discusses the effects of radioactivity on biological treatment processes.

The activated sludge and trickling filter processes have been investigated at Los Alamos by Newell *et al.* (3) (4). As a result of these studies, it was found that 90 to 95 per cent of tracer quantities of Pu^{239} could be removed from aqueous waste solutions during a 23-hr. aeration period. In comparative studies of the chemical precipitation process and of the trickling filter process for removing Pu^{239} from laundry wastes, the trickling filter process appeared the more attractive on the basis of the smaller amount of radioactive sludge to be handled. Both processes, however, were found to effect a substantial removal of Pu^{239} from the wastes.

The present paper describes studies in the removal of carrier-free I^{131}, in the iodide form, from sewage by laboratory trickling filters operating at a 2-m.g.a.d. dosage rate. Preliminary studies by Straub (5) pointed to the feasibility of employing laboratory trickling filters for the removal of carrier-free I^{131}.

Equipment

Lucite columns of 2-in. diameter and 6-ft. depth filled with 0.5- to 1-in. limestone of local origin were used as filters (Figure 1). Sampling ports, consisting of perforated plate valves with bypass, were provided at each foot of depth. In this study, four filters were employed. Figure 2 is a close-up view of the filter columns showing the darkening of the filter media due to slime growth. The two columns at the left were not used in the study and show the intitial appearance of the filters.

A Harvard-type rotary displacement pump fed settled sewage to the trickling filters through ⅛-in. gum rubber tubing.

Procedure

Raw sewage from the Oak Ridge National Laboratory (ORNL) plant sewer system was collected and settled for 1 hr. Analyses indicated that the settled sewage was very weak, having a B.O.D. (5-day, 20° C.) range

* An abridgment of a thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Public Health Engineering, Georgia Institute of Technology, 1951.

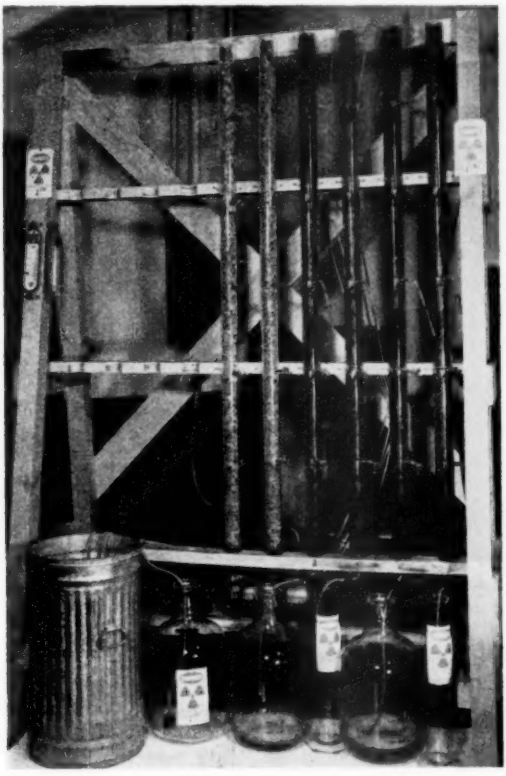

FIGURE 1.—General view of laboratory trickling filters for I^{131} removal studies.

of 45 to 220 p.p.m., with 95 per cent of the values below 100 p.p.m.

"Standard Methods" (6) procedure was followed in the preparation of all reagents and for the analyses themselves. The sodium azide modification of the Winkler method was used in all D.O. determinations.

Temperature and pH measurements were made at various times during the course of the work. Influent temperatures ranged from 68° to 77° F.; pH ranged from 7 to 8. The same determinations on the effluent ranged from 68° to 86° F. and pH 7 to 9, respectively. In general, the pH and temperature of the effluent were slightly higher than those of the influent.

Carrier-free I^{131} (iodide in a weak basic sodium sulfite solution) was obtained from the Operations Division, ORNL, an I^{131} stock solution was prepared, and sufficient amounts of this were added to the settled sewage feed solution to provide an initial concentration of about 1,000 counts per minute per milliliter.

After I^{131} was added, raw and effluent samples were collected, placed in aluminum dishes, dried under infrared lamps, and counted in a Geiger-Muller end-window counter having a geometry of approximately 10 per cent.

Between runs employing iodine tracer, the filters were dosed with settled sewage. During the initial filter maturing period, one filter sloughed off from an unknown cause and was rehabilitated rapidly using a sewage

FIGURE 2.—Close-up of experimental filters to show slime growth (right four) as compared with initial condition (left two).

fortified with 200 p.p.m. of flour and glucose in a 4:1 ratio by weight (7).

Results and Discussion

As the areas of the filters used in this study were small, it was deemed advisable to evaluate filter performance, testing settled sewage alone, on the basis of B.O.D. removal. Results of 31 preliminary runs are summarized in Table I. For a 6-ft. depth of filter, the data indicate that B.O.D. removals of approximately 92, 85, and 76 per cent were obtained by the filters (with no additional treatment) at dosage rates of 2, 4, and 6 m.g.a.d, respectively. These relationships may be best seen in Figure 3, where B.O.D. remaining in the effluent is plotted as a function of filter depth and dosage rate.

After the filters were operating satisfactorily (as indicated by the B.O.D. removals previously mentioned), sewage containing carrier-free I^{131} was added to the filters at a constant dosage rate of 2 m.g.a.d and the removal of I^{131} was studied as a function of bed depth. The results of 15 runs, with variable bed depth ranging from 1 to 6 ft., have been averaged and are presented as trends in Figure 4.

TABLE I.—B.O.D. Removal as a Function of Depth and Dosage Rate

No. of Runs	Sampling Depth (ft.)	Dosage Rate (m.g.a.d.)	Infl. B.O.D. (p.p.m.)	Effl. B.O.D. (p.p.m.)	B.O.D. Removed (%)		
					Min.	Max.	Av.
6	3	2.01	60.1	18.5	47.1	88.0	69.2
5	6	1.99	58.2	4.8	86.8	96.5	91.8
5	3	3.90	104.5	40.7	54.2	66.6	61.1
5	6	4.03	77.1	11.2	80.7	91.2	85.5
4	3	6.14	90.8	45.6	46.8	53.3	49.8
6	6	6.02	82.6	19.8	66.9	83.4	76.0

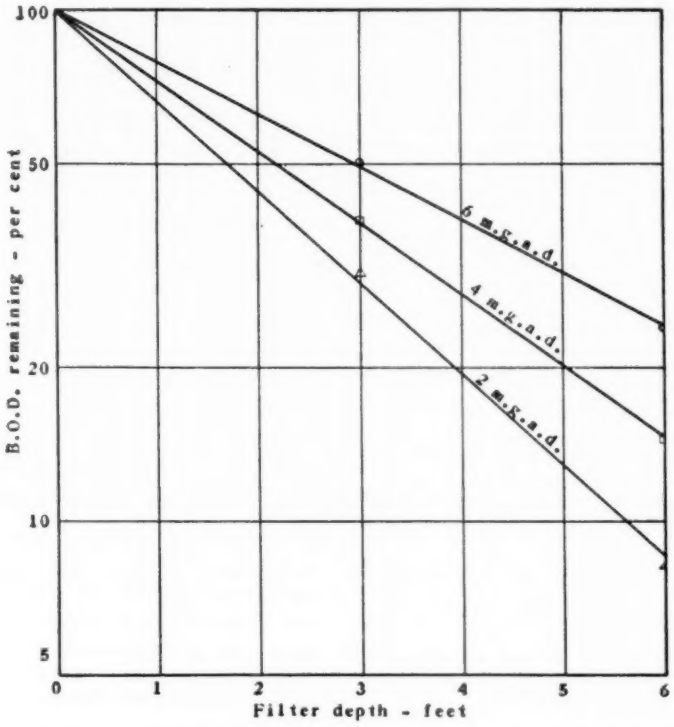

FIGURE 3.—Relationship between B.O.D. remaining and filter depth for three dosage rates.

From Figure 4, it appears that equilibrium conditions were approached after approximately 30 hr. and that for a 6-ft. bed depth a removal of I^{131} in excess of 85 per cent was obtained when the filters were dosed at a rate of 2 m.g.a.d. These results are based on runs not exceeding 30-hr. duration. (The length of a run is the continuous time the I^{131}-settled sewage mixture was fed into the filters.) No data were obtained for time periods less than 30 min.

To determine the I^{131} concentration of the filter slimes, several stones were taken from each filter at the 1-ft. depth and the slimes were scraped and washed from the stones, placed in tared dishes, dried, and counted. The results are presented in Table II. The fluctuation in results (counts per minute per gram dry weight) are thought to be caused in part by self-absorption.

The data of Table II indicate a maximum I^{131} concentration of about 1×10^6 counts per minute per gram of

TABLE II.—Concentration of I^{131} in Filter Slime

Sample No.	Filter No.	Counts per Minute[1]	Sample Weight (g.)	Counts per Unit Weight[2]
1	2	2,401	0.0127	189,000
2	2	4,644	0.0225	206,000
3	2	6,055	0.0599	101,000
1	4	5,863	0.0331	177,000
2	4	3,859	0.0199	194,000
3	4	8,142	0.0406	201,000

[1] Corrected for coincidence and background.
[2] Counts per minute per gram dry weight; the magnitudes of these data are increased approximately five-fold when decay is taken into consideration.

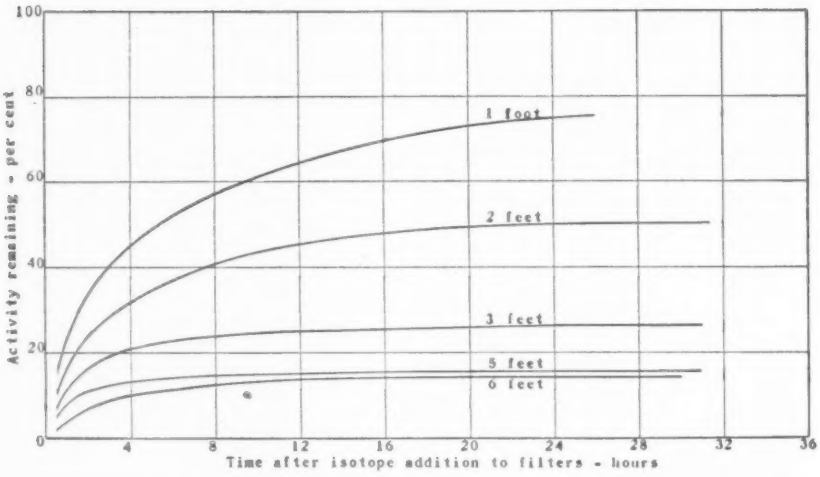

FIGURE 4.—Activity remaining at various times after isotope addition to filters for stated depth.

slime. These data are significant, in that they show a concentration factor of about 1,000 by the slimes. In such a case, the I^{131} activity in the filter slimes amounts to 4.5 μc. per g. on the basis of dry weight.

Summary and Conclusions

Four laboratory trickling filter columns were operated at three dosage rates, all in the low-rate range, to determine their operational characteristics. The B.O.D. (5-day, 20° C.) test was used in this phase of the work and removals of approximately 92, 85, and 76 per cent were obtained by the filters at dosage rates of 2, 4, and 6 m.g.a.d, respectively, at a depth of 6 ft.

Settled sewage, "spiked" with a concentration of 1,000 counts per minute per milliliter of carrier-free I^{131}, was passed through the filter columns and the removal of activity determined at any one of six sampling points located at various filter depths. This arrangement provided data for the correlation of filter depth and I^{131} removal at a dosage rate of 2 m.g.a.d.

Based on the procedures used and the test conditions existent in the laboratory at the time of the tests, approximately 85 per cent removal of carrier-free I^{131}, in the iodide form, was obtained at a dosage rate of 2 m.g.a.d. by 6 ft. of filter bed. It should be pointed out that such high I^{131} removal might not be obtained in municipal practice.

Acknowledgments

An expression of sincere appreciation is given the Oak Ridge Institute of Nuclear Studies, which granted an AEC fellowship, and to the Waste Disposal Research and Development Section, Health Physics Division, Oak Ridge National Laboratory, where the project was carried out.

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CHANGES IN D. C. SANITARY GROUP

Appointment of David Auld as Director of Sanitary Engineering for the District of Columbia was recently announced, following the death a short time ago of the former Director, Harold A. Kemp. Mr. Auld had been Deputy Director under Mr. Kemp.

Also announced was the appointment of Ralph E. Fuhrman to the Deputy Director post vacated by Mr. Auld's promotion. At the time of his appointment Mr. Fuhrman was Superintendent of the District of Columbia sewage treatment plant. He also is a Past President of the Federation and of the Maryland-Delaware Water and Sewerage Association.

As reorganized, the Department of Sanitary Engineering has responsibility for water distribution, storm and sanitary sewers, sewage treatment, and all refuse collection and disposal. Besides extensive operations in the other fields, there is at present under construction at the sewage treatment plant a $2,500,000 sludge drying and incineration plant. Other proposed major additions include chlorination and high-rate activated sludge units, on which construction is scheduled to begin within the year.

DEOXYGENATION OF SEWAGE*

III. The Logarithmic Formula Applied to Oxidations Other Than Sewage

By Harold E. Orford and William T. Ingram

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In the first paper of this series (1) a new mathematical formulation for biological oxidation was presented (Eq. 9). The new formulation, known as the "logarithmic equation," in Part II of this series of papers (1) was applied only to the biological oxidation of sewage. A limited investigation has been made of its application to the following:

1. Biological oxidation of different types of substrate.
   a) River water.
   b) Industrial wastes.
   c) Sewage sludges.
2. Other types of biological oxidation.
   a) Benthal oxidation.
   b) Activated sludge oxidation.
3. Determination of the oxygen sag curve with combined deoxygenation and reaeration.

The observations here presented are not complete, and are only intended to show possible applications of the logarithmic equation to biological oxidation in general.

Application to River Water

From a study of a few river-water B.O.D. curves taken from Theriault's (2) work, it has been found that the logarithmic equation can apparently be applied to river-water oxidation. The oxidation speed of river water is usually less than that of sewage, and a values are correspondingly lower. Figure 8 shows a long-time B.O.D. study on Ohio River water at 20° C., with the constants for both the logarithmic and monomolecular equations. Figure 9 shows logarithmic B.O.D. curves for river water at 30°, 20°, and 10° C. These are taken from some of Theriault's (2) work to determine the effect of temperature on k values. The logarithmic and monomolecular constants for these equations are given in Table IV.

The relationship between **a** values and temperature is the same as that found for sewage, and it appears that the value of **a** doubles for each 10° rise in temperature between 10° and 30° C. for materials other than sewage.

Application to Industrial Wastes

The oxidation of a few industrial wastes was analyzed by the monomolecular and logarithmic equations. This group included: corn products waste, reported by Mohlman, Edwards,

TABLE IV.—Logarithmic and Monomolecular Equation Constants for the B.O.D. of River Water at Various Temperatures

Temp. (°C.)	a	S	k	L
9	0.25	4.2	.0508	4.58
20	0.50	4.93	.0993	5.52
30	1.00	4.83	.1501	6.24

Temperature constant, θ, = 1.070 (logarithmic equation)
Temperature constant, θ, = 1.054 (monomolecular equation)

* Presented at 25th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; New York, N. Y.; Oct. 6–9, 1952.

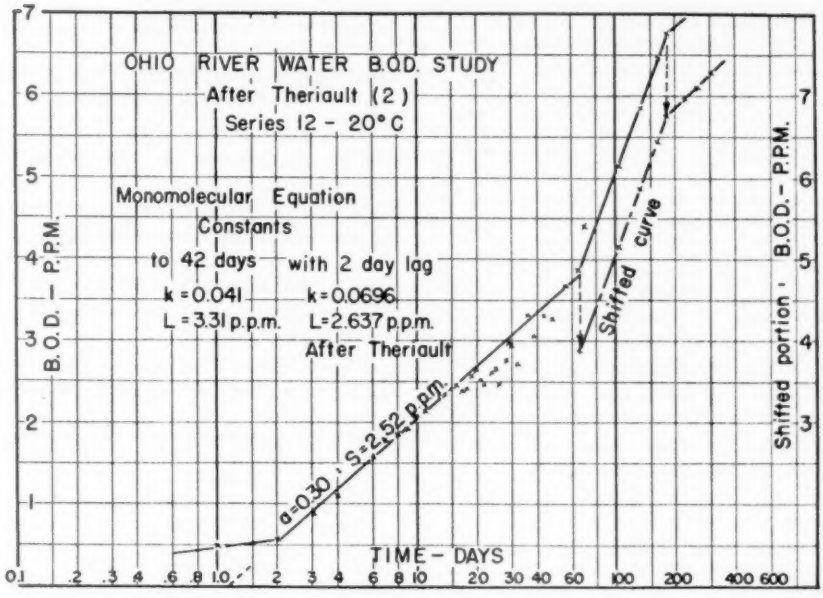
OHIO RIVER WATER B.O.D. STUDY
After Theriault (2)
Series 12 - 20° C
Monomolecular Equation
Constants
to 42 days with 2 day lag
k = 0.041 k = 0.0696
L = 3.31 p.p.m. L = 2.637 p.p.m.
After Theriault
a = 0.30 ; S = 2.52 p.p.m.
Shifted curve
B.O.D. - P.P.M.
Shifted portion - B.O.D. - P.P.M.
TIME - DAYS

FIGURE 8.

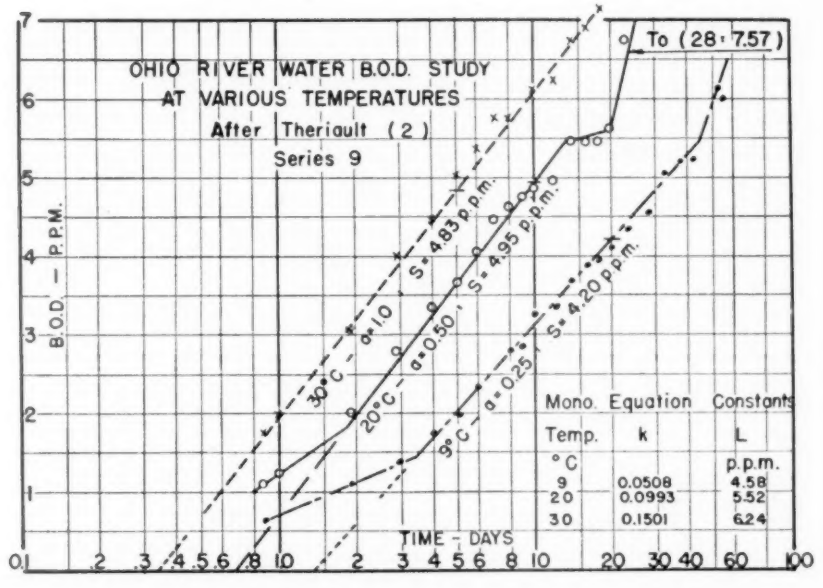
OHIO RIVER WATER B.O.D. STUDY
AT VARIOUS TEMPERATURES
After Theriault (2)
Series 9
To (28 · 7.57)
30° C - a = 1.0 ; S = 4.83 p.p.m.
20° C - a = 0.50 ; S = 4.95 p.p.m.
9° C - a = 0.25 ; S = 4.20 p.p.m.
Mono. Equation Constants
Temp. k L
°C p.p.m.
9 0.0508 4.58
20 0.0993 5.52
30 0.1501 6.24
B.O.D. - P.P.M.
TIME - DAYS

FIGURE 9.

TABLE V.—Logarithmic and Monomolecular Equation Constants for the B.O.D. of Various Industrial Wastes

Waste	a	S	k	L
Corn products	0.50	417	.114	411
Paper board	0.83	421	.140	516
Sugar	0.67	590	.114	658
Sugar plus sewage	1.67	565	.275	686

and Swope (3); paper board white water, reported by Amberg (4); sugar, reported by Holderby and Lea (5); and a sugar waste plus sewage analyzed for this investigation. Figure 10 shows the logarithmic B.O.D. curves for this group and Table V gives a comparison between the logarithmic and monomolecular equation constants for the group. Values of k and L are given for 5-day observation periods.

For these wastes the logarithmic equation follows the observed points as well as it does for sewage, if not better. Specialized wastes oxidized alone appear to oxidize more slowly than sewage, whereas the oxidation of sugar waste with a large proportion of sewage is apparently accelerated.

Application to Sewage Sludges and Benthal Oxidation of Sludges

The aerobic oxidation of sewage sludge is shown by the two curves on the left side of Figure 11. The data obtained by Fair (6) for the oxidation of raw and digested sewage sludges closely follows the logarithmic equation. The logarithmic and monomolecular equation constants are given in Table VI.

From the relative values of **a** and S it appears that the organic material

TABLE VI.—Logarithmic and Monomolecular Equation Constants for the B.O.D. of Sewage Sludges

Sludge	a	S[1]	k	L[1]
Raw	0.40	510	0.105	715
Digested[2]	0.25	379	0.0414	454

[1] Grams of oxygen demand per kilogram of volatile solids.

[2] Same sludge after digesting for 450 days.

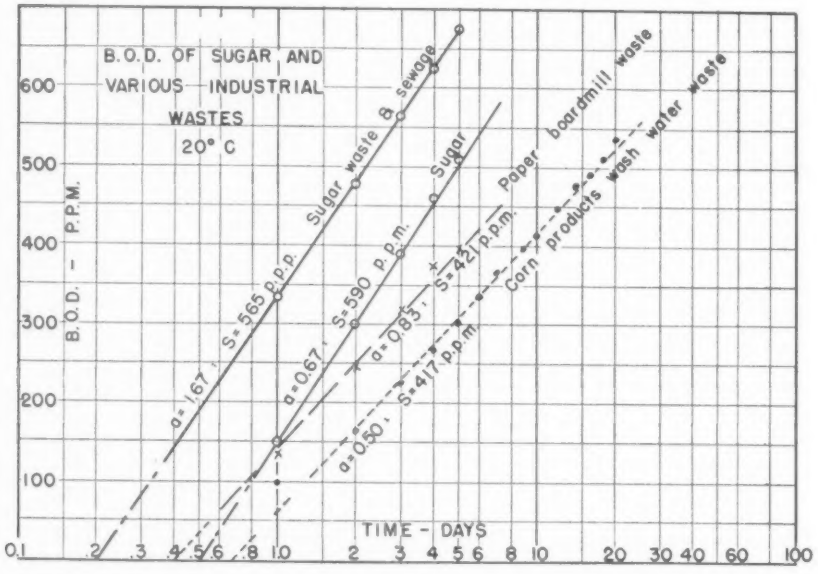

FIGURE 10.

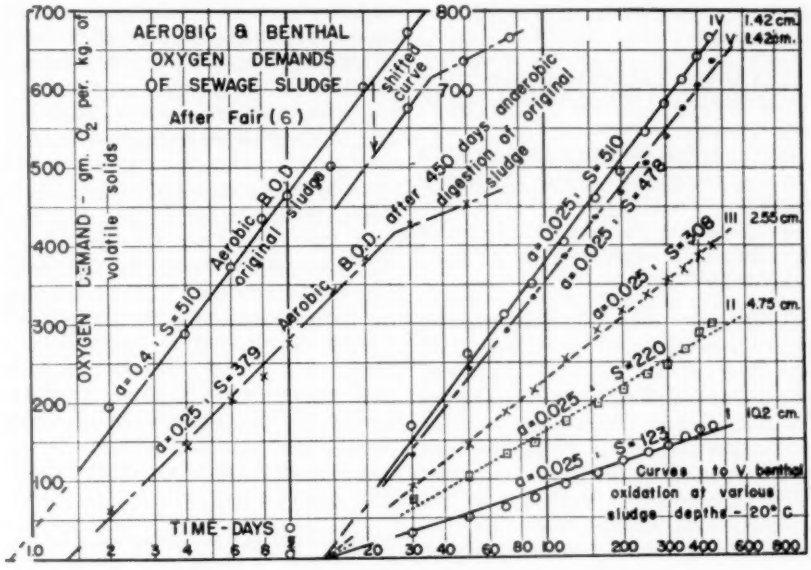

FIGURE 11.

remaining in a well-digested sludge oxidizes slightly more slowly and requires less oxygen for stabilization than the original organic material in the raw sludge.

The application of the logarithmic equation to the benthal oxidation of sewage sludge also is shown in Figure 11, curves I to V giving the results of benthal oxidation at various sludge depths of the same raw sewage sludge previously discussed. A benthal oxidation system has both aerobic and anaerobic elements. In general, a benthal system gradually changes from a completely aerobic environment in the top layers to a partially or completely anaerobic environment in the bottom layers. The degree of anaerobiosis in the bottom layers increases with increasing sludge depth. This change is one of the most important factors of benthal oxidation. The logarithmic and monomolecular equation constants are given in Table VII.

From the results of the logarithmic

TABLE VII.—Logarithmic and Retardant Monomolecular Equation Constants for the Benthal Oxidation of Sewage Sludge at Various Sludge Depths

Curve	Sludge Depth (cm.)	Logarithmic Equation		Simple Monomolecular Equation		Retardant* Monomolecular Equation		
		a	S_t†	k	L_t†	k	L_t†	a
I	10.2	0.025	123	0.00674	172	0.00628	198	0.00240
II	4.75	0.025	220	0.0101	260	0.00726	309	0.00245
III	2.55	0.025	308	0.0103	377	0.00750	447	0.00301
IV	1.42	0.025	478	0.00869	641	0.00762	758	0.00373
V	1.42	0.025	510	0.0102	587	0.00764	710	0.00369

* Eq. 5.

† Oxygen demand, in grams O_2 per kilogram of volatile solids.

analysis, the following observations can be made:

1. The speed of benthal oxidation is approximately 1/40 that of standardized domestic sewage.
2. The speed of benthal oxidation is not significantly changed by sludge depth.
3. Increasing sludge depth decreases the amount of organic material available for oxidation.

These observations are supported by known and observed phenomena. It was observed that the oxidation speed of the digested sludge was only slightly less than that of the raw sludge. The benthal environment reduced the sludge oxidation speed 10 to 16 times, so that differences between benthal oxidation speeds of aerobic and anaerobic portions of the sludge probably become insignificant. Anaerobic decomposition converts organic material chiefly to methane and carbon dioxide, which are removed and not available for oxidation. As the sludge depth increases, anaerobic decomposition increases and a lesser proportion of the organic material is available for benthal oxidation. This is reflected by the decreasing S value with increasing sludge depth.

Some of the observations made from the logarithmic equation analysis differ from the conclusions reached by Fair (6) from the monomolecular equation analysis of the data. He concluded that the speed of benthal oxidation was significantly reduced by increasing depth of sludge and that the character of the benthal oxidation changed with depth. Further study is necessary to determine whether benthal oxidation differences are caused by a significant change in the character of the oxidation or merely by differences in the proportion of organic material available for oxidation.

Application to Activated Sludge Oxidation

An application of the logarithmic equation to activated sludge oxidation is shown in Figure 12. The data used are from the work by Gellman (7) on the oxidation of industrial wastes by

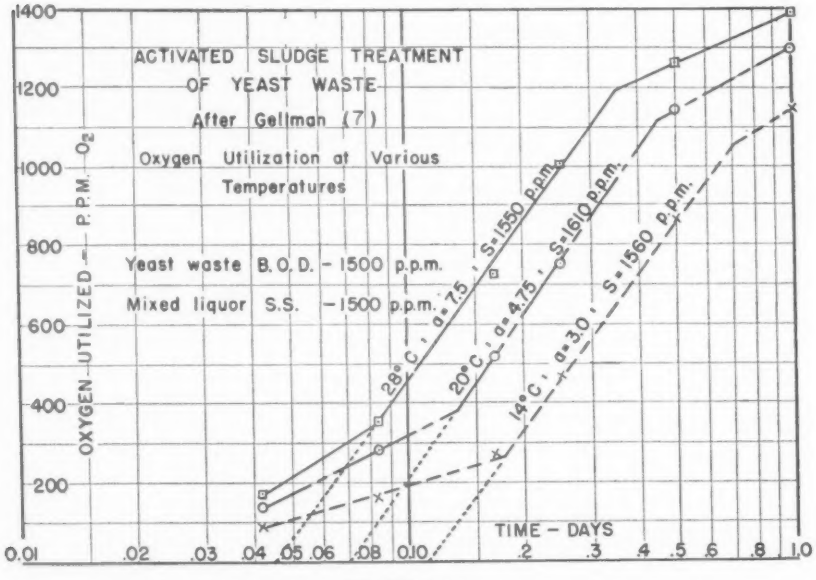

FIGURE 12.

activated sludge. The oxygen utilizations of the sludge itself and the sludge-waste mixture were both measured with the Warburg apparatus. The plotted points represent the oxygen utilization of the waste and were obtained by subtracting the oxygen demand of the sludge from the oxygen demand of the mixture. The waste used was spent yeast waste with a 5-day B.O.D. of 1,500 p.p.m., and the activated sludge mixed liquor concentration was also 1,500 p.p.m. for the three tests illustrated. The plotted curves show a tendency to break into three stages similar to those observed for the carbonaceous B.O.D. of sewage: first, a short-period initial oxidation stage; next, a secondary stage, during which most of the oxidation takes place; and finally, a third stage characterized by reduced oxidation rates.

Table VIII gives the a and S values of the second stage for three different temperatures and the corresponding k and L values for the 24-hr. observed B.O.D. curve.

The temperature constant, θ, for the tests is 1.068, which is practically the same as that found for sewage, 1.072 (1). The S value variation is about the same as that observed for sewage and is no more than the expected variation in the B.O.D. test itself. There is no apparent relationship between S value and temperature, and variations are possibly caused by accumulated deviations in observed data and mathematical analysis.

The observed points are too few to establish good logarithmic fits to the data, but the analysis does show a possible use for the logarithmic equation in the analysis of activated sludge oxidation.

TABLE VIII.—Logarithmic and Monomolecular Equation Constants for the Oxidation of Yeast Waste[1] by Activated Sludge[2] at Various Temperatures

Temp. (°C.)	a	S (p.p.m.)	k	L (p.p.m.)
14	3.0	1,560	0.70	1,470
20	4.75	1,610	1.48	1,360
28	7.5	1,550	2.10	1,395

[1] 5-Day B.O.D., 1,500 p.p.m.
[2] Mixed liquor suspended solids, 1,500 p.p.m.

Application of Monomolecular Equation to Oxygen Sag Curve Analysis

The rate of oxygen uptake for water is proportional to the oxygen undersaturation. This can be expressed as a monomolecular-type differential equation

$$\frac{dD}{dt} = k_2 D \quad \ldots\ldots\ldots (17)$$

in which D is the oxygen undersaturation, in p.p.m. dissolved oxygen, and k_2 is the reaeration constant.

The equation for the combined effect of deoxygenation and reaeration is reported by Fair (8) as

$$D = \frac{k_1 L_a}{k_2 - k_1} \times (10^{-k_1 t} - 10^{-k_2 t}) + D_a 10^{-k_2 t} \quad \ldots\ldots (18)$$

in which

D = the oxygen deficit at the time of flow, t, from the reference point;
t = time, in days;
L_a = ultimate first-stage oxygen demand at the reference point;
D_a = the initial dissolved oxygen deficit at the reference point;
k_1 = the first-stage deoxygenation rate constant of the monomolecular equation (k); and
k_2 = the reaeration constant of the stream.

Attempts were made to develop a similar combined equation for deoxygenation and reaeration using the logarithmic deoxygenation equation and the monomolecular reaeration equation. All efforts to develop a usable combined equation were unsuccessful because of basic mathematical differences in the two equations. The logarithmic equation expresses oxygen utilization as a

function of the logarithm of time, whereas the reaeration equation expresses time as a function of the logarithm of the oxygen deficit.

Since it was not possible to change the monomolecular form of the reaeration equation, an attempt was made to express k_1 and L_a in terms of **a** and S so that the combined deoxygenation-reaeration could be used.

Relationship between the Logarithmic and Monomolecular Equation Constants

The logarithmic and monomolecular equations are mathematical approximations to a B.O.D. curve. Both equations are logarithmic in form. The monomolecular equation can be written

$$\log (L - y_t) = -k\,t \ldots (19)$$

The logarithmic equation is

$$y_t = S\,(0.85 \log \mathbf{a}t + 0.41) \ldots (9)$$

The two equations are not identical for all values of y_t and t, so it is impossible to combine the two equations and solve for the constants of one in terms of the constants of the other. However, an approximate mathematical relationship exists between the respective constants, and k and L can be simply and closely expressed as functions of **a** and S.

The general logarithmic equation (Eq. 9) can be approximated by a series of monomolecular equations computed for different times of observation, as follows:

Time	k	L
3 days	0.218 **a**	1.04 S
5 days	0.197 **a**	1.10 S
7 days	0.180 **a**	1.16 S
10 days	0.150 **a**	1.25 S
14 days	0.130 **a**	1.34 S

The value of k decreases and the value of L increases with increasing time of observation in observed B.O.D. curves. This same relationship also is observed in the values of k and L calculated from the logarithmic equation curve of best fit.

The k and L values given were computed by the simplified method for the analysis of B.O.D. data developed by Moore *et al.* (9). For the computation, **a** was given a value of unity. After k and L values were determined for the standardized curve, the k and L values were determined for any other time ratio by merely multiplying k by the time ratio, **a**. A similar transformation is suggested by Moore for extending the time range of prepared curves for computation of monomolecular equation constants. Thus, the simple approximate relationship between the constants makes it possible to compute the monomolecular equation constants from the logarithmic equation constants.

The relationship holds for only the simple monomolecular equation. If a time lag parameter or a retardant parameter is used with the monomolecular equation, the relationship does not apply.

For practical use of the relationship between the constants of the two equations, the 10-day values of the constants were chosen as good parameters to express the entire curve. Thus, $k = 0.150\,\mathbf{a}$ and $L = 1.25\,S$. The values of k and L computed from this relationship will not necessarily be the same as those computed by standard monomolecular equation methods, but they will give a deoxygenation curve that will be a close approximation to observed B.O.D. values. It is not suggested that this relationship be used to compute k and L values for a monomolecular curve, but it is suggested that this relationship possibly can be used to compute oxygen sag curves by substituting logarithmic equation constants for monomolecular equation deoxygenation constants in the oxygen sag equation, which would then be expressed as:

$$D = \frac{0.15\,\mathbf{a}\,(1.25\,S)}{k_2 - 0.15\,\mathbf{a}} \times (10^{-0.15\,\mathbf{a}\,t} - 10^{-k_2 t}) + D_a\,10^{-k_2 t} \ldots (20)$$

To compare the curves obtained by the two equations, oxygen sag curves were computed for the Ohio River B.O.D. sample at 20° C. analyzed by Theriault (2) and shown in Figure 2. One curve was computed by Eq. 18, using k and L values determined by Theriault; the other was computed by Eq. 20. The computed oxygen sag curves are shown in Figure 13, which shows that the oxygen sag curves calculated by the two methods are very close to each other and that for all practical purposes the curves can be considered identical. Differences in dissolved oxygen are generally less than 0.2 p.p.m. and the minimum D.O. level and the time of occurrence are practically the same. If it is considered that the accuracy of the D.O. determination is 0.1 p.p.m., that reaeration constants of natural streams are seldom known within 25 per cent accuracy, and that reaeration constants of streams vary from point to point, it is possible to conclude that for all practical purposes these oxygen sag curves are identical.

Possible Application of Logarithmic Equation to B.O.D. Test

There are several difficulties involved in the standard B.O.D. test. It is possible that two of these difficulties may be overcome by use of the logarithmic equation. The first is the relatively long 5-day interval required before the test is completed; the second is that the standard 5-day B.O.D. test measures B.O.D. without evaluating the effect of differences in oxidation rate.

If two short-period B.O.D. observations were made, say 1- and 2-day or 1- and 3-day B.O.D.'s, the **a** and S values could be readily determined and the curve projected with reasonable accuracy. The logarithmic B.O.D. formula offers a new approach to the problem of shortening the B.O.D. test period. With further research a modified standard B.O.D. test might be developed which would shorten the test

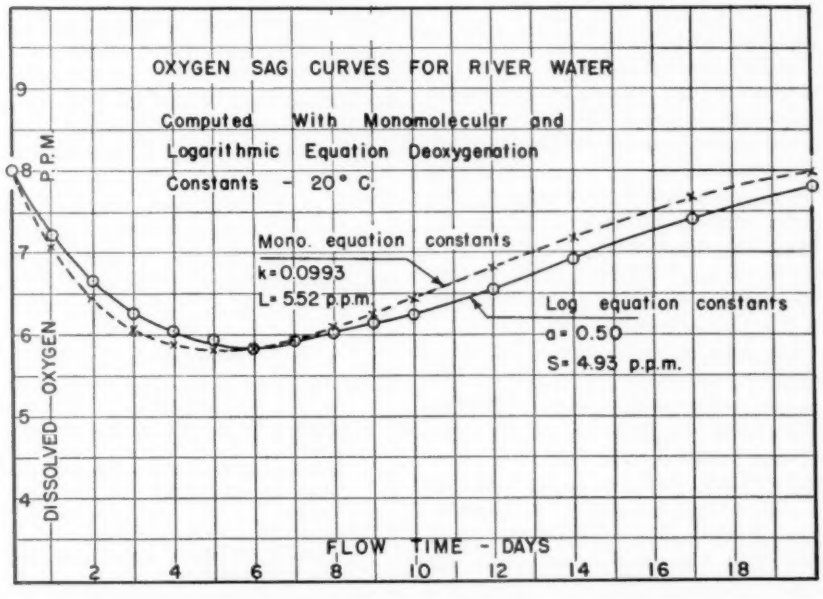

FIGURE 13.

period and give greater significance to the 5-day B.O.D. value. The form of the logarithmic equation should be suited for such a modification because the parameter S is a modified 5-day B.O.D. value. Thus, a simple modified test might use S as a measure of B.O.D. strength instead of 5-day B.O.D. It is conceivable that S would have a greater significance than 5-day B.O.D. because oxidation speed is reflected in the value of S.

Summary

In a previous paper (1) a new, simpler mathematical equation to express biological oxidation of sewage was developed which gives as good a fit to observed B.O.D. data as the monomolecular equation and eliminates many of the difficulties of the latter, including instability of the constants and complicated calculations. The equation, known as the "Logarithmic B.O.D. Equation," has the general form

$$y_t = S\,(0.85 \log \mathbf{a}\, t + 0.41) \ldots (9)$$

The various terms are defined where they first appear. The oxidation rate at time t is proportional to the strength parameter, S, and inversely proportional to the time. In the monomolecular equation the oxidation rate at time t is proportional to the amount of material remaining to be oxidized, $L - y_t$. Thus, the logarithmic equation is a fundamentally different mathematical expression and is not a reformulation of the monomolecular equation.

The logarithmic equation has been applied successfully to biological oxidations other than sewage. Illustrations of the applications of the logarithmic equation were limited in scope and sufficient evidence is not available to show its reliability. However, enough evidence is available to suggest that the logarithmic equation will apply to several types of biological oxidations without change in form of the basic equation. These applications include:

1. Biological oxidation of river water.
2. Activated sludge oxidation.
3. Benthal oxidation of sewage sludges.
4. Biological oxidation of industrial wastes.

A simple method was developed which makes it possible to use the logarithmic B.O.D. parameters, **a** and S, in the monomolecular oxygen sag equation, for computing simultaneous deoxygenation and reaeration. It was found that k and L values sufficiently accurate for such use could be computed from the simple relationship: $k = 0.15$ **a** and $L = 1.25\ S$.

Acknowledgments

In completing this research it was advantageous to utilize facilities available at both Rutgers University and New York University. Unpublished information and helpful advice have been received from Drs. Gail P. Edwards and William E. Dobbins of the College of Engineering, New York University, and Drs. Willem Rudolfs and H. Heukelekian of the Department of Sanitation, Rutgers University. The authors wish to thank all of them for their assistance.

The paper, in three parts, was prepared from a thesis having the same title accepted by the faculty of the Graduate Division, College of Engineering, New York University.

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FIRST VIRGINIA SANITATION AUTHORITY FORMED AT ALEXANDRIA

Formation in January, 1953, of the City of Alexandria (Va.) Sanitation Authority was noteworthy as the first such agency to be created in that state under the authorizing statutes passed in 1950.

The Authority is charged with arranging the financing, construction, and operation of intercepting sewers, pumping stations, and sewage treatment facilities for Alexandria and portions of neighboring Fairfax County. The initial construction program which contemplates an expenditure of $9,500,000, will be an integral part of the program of the communities in the Washington, D. C., metropolitan area to abate pollution in the Potomac River.

Appointment of James J. Corbalis, Jr., to the post of Engineer-Director of the Authority recently was announced. Mr. Corbalis was Sanitary Engineer of Fairfax County, Va., at the time of his appointment to the new position.

Industrial Wastes

ANAEROBIC DIGESTION OF PACKING PLANT WASTES

By W. J. Fullen

Chemist, Service Division, George A. Hormel and Co., Austin, Minn.

Anaerobic treatment of packing-house wastes has been under investigation by Geo. A. Hormel & Co. for the past 3½ years. The initial laboratory work was done in 55-gal oil drums. After working a year with this laboratory unit, the results looked promising enough to warrant larger-scale investigation.

The work on the pilot-plant unit was started in July, 1950. Basically, the process consists of mixing in a digester the incoming raw waste with an activated anaerobic sludge at a temperature of 92° to 94° F., and then effecting a separation of sludge from the mixture and returning it to the digester. Many changes were made in the different units during this investigation.

Pilot-Plant Units

The following is a description of the different units of the pilot plant as it is operating successfully at the present time:

1. The holding tank, of 412-cu. ft. capacity, is 8 ft. square with 6-ft. sidewall depth and hopper bottom of 45° slope. The tank is insulated and equipped with a constant-level supply box, from which the raw waste is fed to the digester.

2. The digester is contiguous with the supply or holding tank. It is 16 ft. by 8 ft. in plan, with sidewall depth of 6 ft. and a double hopper bottom. The contents are heated by passing the digester recirculation flow through a heat exchanger utilizing live steam to heat a water bath around the 3-in. digester recirculation line. The temperature of the digester contents is controlled by a temperature recorder and controller instrument. The digester is completely insulated and gas is discharged to the atmosphere. A circulating pump draws the liquid from the two bottom hoppers and discharges on splash plates in the tank.

3. A degassing chamber, operated under a 25- to 26-in. vacuum, is equipped with a series of plates over which the effluent from the digester cascades. The vacuum chamber is situated on the top of a barometric leg (36-ft. height). The vacuum is produced by means of a Duriron water ejector, with raw sewage being pumped as the water supply for the ejector. The effluent from the digester flows continuously into the vacuum chamber, where it is held for 5 to 10 min. and then discharged to the clarifier. The difference in height of the water in the feed and discharge legs of the vacuum system causes the flow, and this in turn is caused by the discharge from the digester. The detention time in the vacuum chamber is regulated by raising or lowering the clarifier feed box, located on the discharge leg of the barometric leg.

4. The rectangular clarifier (8 ft. by 4 ft. by 3 ft. high) has an effective capacity of 93.4 cu. ft. The influent enters through a perforated pipe located about 1 ft. below the surface. A slotted baffle in front of the perforated

feed pipe seems to give good distribution.

Sludge is removed hydraulically at a continuous rate through two slotted pipes that scavenge the bottom by moving at a rate of $\frac{3}{8}$ ft. per minute. A reversing mechanism causes the back and forth movement of the scavenger pipes. Removed sludge is discharged back to the digester. The present rate of feed to the clarifier gives about 1-hr. detention in this unit.

The discharge from the clarifier is taken off through a notched effluent weir. A manually-operated scum trough is provided for use when necessary.

Prior to installation of the vacuum system (Figure 1) and clarifier, separation of the sludge from the effluent was effected by allowing it to discharge into a separation tank of one-half the size of the digester. The sludge would both rise and settle and a fairly clear effluent could be drawn off from between the two layers. This was further clarified by flocculation and sedimentation. Sludge was removed from both the top and the bottom of this unit.

Operational Changes

Inasmuch as changes in operation were made over the test periods reported, appropriate designation for each test is given, as follows:

Period No. 1—October 17, 1950, to March, 1951. The flow diagram during this period was as shown in Figure 2, except that the filter, Imhoff tank, and flocculator were not included.

Period No. 2—August, 1951, to December, 1951. Tests during this period were run under the conditions shown in Figure 2.

Period No. 3—January 1, 1952, to March 31, 1952. The plant during this period was run under the conditions shown in Figure 2, except that the separator underflow and top sludge were returned to the digester influent instead of to the holding tank. Sampling points 1, 2, and 3 were on the raw waste line, Imhoff tank effluent, and filter effluent, respectively.

Period No. 4—May 1–20, 1952. This

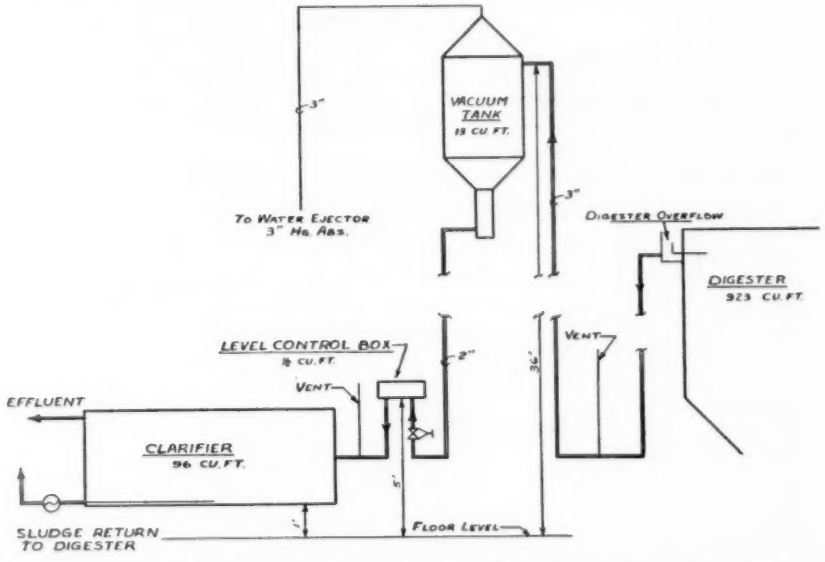

FIGURE 1.—Flow diagram of vacuum system on packinghouse waste treatment at Hormel pilot plant, Austin, Minn.

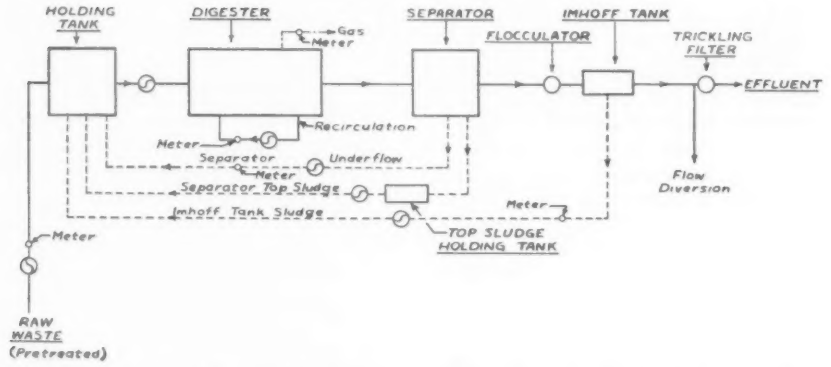

FIGURE 2.—Flow diagram of anaerobic packinghouse waste treatment system prior to Jan. 1, 1952.

run was made under the conditions of Period No. 3 after changing circulation discharge.

Period No. 5—August 14, 1952, to September 23, 1952. The plant was run under the conditions shown in Figure 3.

Analytical results for the several periods are given in Tables I, II, III, IV, and V, respectively. Loadings and efficiencies of the various units for the several test periods are given in Table VI.

Metering and Sampling

The waste being treated is a composite of what might be termed typical packinghouse wastes. Although the Hormel Co. purposely segregates condenser waters from the industrial wastes in order to reduce the problem volumetrically, tests have been run on wastes varying in strength from 900 to 2,000 p.p.m. B.O.D. There is every evidence that anaerobic digestion will work very well on weaker wastes and produce effluents of 20 to 35 p.p.m. B.O.D., but the economics are in question and it is suspected that less work is done per unit of digester volume. Another important aspect of the process is that the heat and mineral requirements are largely inherent in raw packinghouse waste.

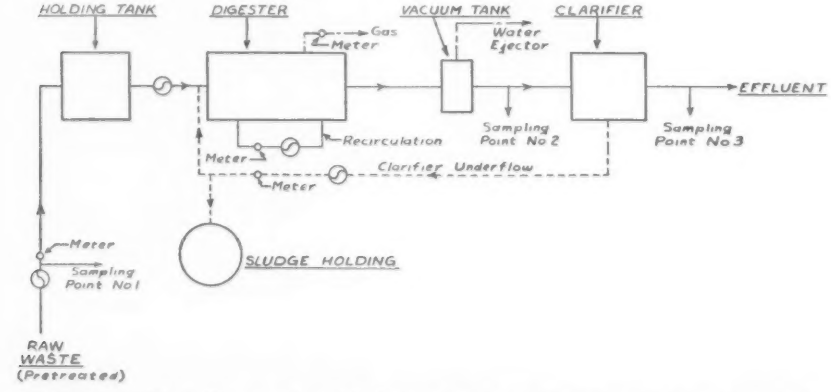

FIGURE 3.—Flow diagram of packinghouse waste treatment system from August 14, 1952, to September 23, 1952.

TABLE I.—Analytical Results, Period 1

Item	Raw Waste	Sep. Effl.
Raw feed (cu. ft./day)	568	—
Sl. return (cu. ft./day)	725	—
Gas (cu. ft./day)	629	—
Total solids:		
P.p.m.	6,610	5,160
Lb./day	234	183
Total vol. sol.:		
P.p.m.	1,925	460
Lb./day	68.2	16.3
Susp. solids:		
P.p.m.	1,050	226
Lb./day	37.2	8.0
B.O.D., 5-day:		
P.p.m.	2,075	119
Lb./day	73.6	4.2

All wastes are metered into the holding tank. Sludge returned to the digester also is metered. Ordinary 1½-in. water meters are used, although it is necessary to remove the top and bottom screens in these meters.

Samples of the raw feed and final effluent are analyzed daily, for the most part by "Standard Methods." The Gooch crucible method for suspended solids has been replaced by a filter paper method. A filter paper is weighed and placed in a large Buechner funnel and the suspended solids filtered by vacuum. A 50-ml. sample is used for raw waste and a 500-ml. sample for the final effluent. A plus or minus correction is made, as determined on a separate filter paper. It is felt that the larger samples taken tend to give accurate results. The speed with which the results can be obtained further enhances the method for routine control.

TABLE II.—Analytical Results, Period 2

Item	Raw Waste	Imhoff Effl.	Filt. Effl.
Raw feed (cu. ft./day)	575	—	—
Sl. return (cu. ft./day)	365	—	—
Imhoff sl. ret. (cu. ft./day)	23.7	—	—
Gas (cu. ft./day)	502	—	—
Total solids:			
P.p.m.	5,410	4,490	3,900
Lb./day	193	161	—
Total vol. sol.:			
P.p.m.	1,500	416	287
Lb./day	53.8	14.9	—
Susp. solids:			
P.p.m.	886	206	382
Lb./day	31.8	7.4	—
B.O.D., 5-day:			
P.p.m.	1,658	89	42
Lb./day	59.4	3.2	—

TABLE III.—Analytical Results, Period 3

Item	Raw Waste	Imhoff Effl.	Filt. Effl.
Raw feed (cu. ft./day)	910	—	—
Sl. return (cu. ft./day)	722	—	—
Imhoff sl. ret. (cu. ft./day)	40	—	—
Gas (cu. ft./day)	883	—	—
Total solids:			
P.p.m.	5,400	4,360	4,340
Lb./day	306	247	—
Volatile solids:			
P.p.m.	1,318	320	270
Lb./day	74.6	18.2	—
Susp. solids:			
P.p.m.	794	162	282
Lb./day	44.9	9.2	—
B.O.D., 5-day			
P.p.m.	1,241	62	32
Lb./day	70.3	3.5	—
Total nitrogen:			
P.p.m.	128	118.5	100
Lb./day	7.24	6.71	—
Ammonia nitrogen:			
P.p.m.	37.0	105	97
Lb./day	2.09	5.96	—
Organic nitrogen:			
P.p.m.	91	13.3	3
Lb./day	5.15	.75	—

Sludge Acclimatization

It was formerly thought that a long period of acclimatization was necessary before the initial sludge used in starting the digester would be capable of rapid digestion. Subsequent experience has changed thinking on this point.

The pilot digester was started with sludge obtained from the digesters at the Austin municipal treatment plant. At various times in the past 3½ years it has been found necessary to replenish the sludge supply. The last time this was done the digester was operat-

TABLE IV.—Analytical Results, Period 4

Item	Raw Waste	Sep. Effl.	Sep.[1] Effl.
Raw feed (cu. ft./day)	1,137	—	—
Sl. return (cu. ft./day)	1,310	—	—
Imhoff sl. ret. (cu. ft./day)	214	—	—
Gas (cu. ft./day)	638	—	—
Total solids:			
P.p.m.	5,100	4,810	4,260
Lb./day	362	341	302
Total vol. sol.:			
P.p.m.	990	620	247
Lb./day	70.3	44.0	17.5
Susp. solids			
P.p.m.	474	571	62
Lb./day	33.6	40.5	4.4
B.O.D., 5-day			
P.p.m.	1,050	140	36
Lb./day	74.4	9.9	2.6

[1] Settled 1½ hr.

TABLE V.—Analytical Results, Period 5

Item	Raw Waste	Clarifier Effluent
Raw feed (cu. ft./day)	893	—
Sl. return (cu. ft./day)	1,246	—
Total solids:		
P.p.m.	5,500	4,460
Lb./day	307	259
Total vol. sol.:		
P.p.m.	1,290	292
Lb./day	72	16.2
Susp. solids:		
P.p.m.	784	39
Lb./day	43.7	2.16
B.O.D., 5-day		
P.p.m.	1,160	42.8
Lb./day	66.4	2.45

ing at a 1-day detention within two weeks. This was done by elutriating the new sludge with fairly clean water for three or four days and then starting the raw feed at a reduced rate, increasing the feed as gas production indicated the ability of the sludge to handle the waste.

It is realized that sludge from the municipal plant's digester is mainly of packinghouse origin. It may be possible that by washing out the end products due to digestion of regular sludge, the culture was peculiarly adapted to rapid digestion of similar but weaker waste.

It might be mentioned that when the laboratory units were in operation two sludges of entirely different origin were run in parallel, performance being identical after a year's operation. One sludge was from the digesters of the Austin municipal plant, the other from the digesters at Crystal Lake, Ill.

Volatile Solids Balance

Calculations showed that in Period 2, 12.2 per cent of the volatile solids were unaccountably destroyed, whereas in Period 3 the unaccounted for destruction was 3.7 per cent. For Period 5, in which the vacuum system was used, the volatile solids data were as given in Table VII.

TABLE VI.—Loadings and Efficiencies for Various Pilot-Plant Test Periods

Item	Period				
	1	2	3	4	5
Raw waste flow (cu. ft./day)	568	575	910	1,137	893
Return sludge (cu. ft./day)	725	388.7	762	1,524	1,246
Feed, vol. sol. (lb./day)	68.2	53.8	74.6	70.3	72
Feed, B.O.D. (lb./day)	73.6	59.4	70.3	74.4	66.4
Removal, vol. sol. (%)	76.2	72.5	75.2	75.0[1]	77.4
Removal, B.O.D. (%)	94.3	94.6	95.0	96.2[1]	96.3
LOADINGS BASED ON BOTH DIGESTER AND SEPARATOR AS BEING EFFECTIVE					
Detention on raw flow (days)	2.38	2.35	1.48	1.19	—
Detention on total flow (days)	1.05	1.40	0.81	0.51	—
Feed vol. sol. (lb./cu. ft./day)	0.050	0.040	0.055	0.052	—
Feed, B.O.D. (lb./cu. ft./day)	0.054	0.044	0.052	0.055	—
LOADINGS BASED ON DIGESTER ONLY AS BEING EFFECTIVE					
Detention on raw flow (days)	1.55	1.53	1.01	0.82	1.03
Detention on total flow (days)	0.68	0.92	0.55	0.35	0.43
Feed vol. sol. (lb./cu. ft./day)	0.078	0.061	0.081	0.076	0.078
Feed, B.O.D. (lb./cu. ft./day)	0.084	0.067	0.076	0.081	0.072

[1] Sample settled in 1½ hrs.

TABLE VII.—Volatile Solids Data for Period 5

Total vol. solids:	
In raw waste (lb.)	2,664
In effluent (lb.)	601
Total gas metered (cu. ft.)	24,700
Gas removed in vacuum tank (cu. ft.)	10,100
Total gas produced (cu. ft.)	34,800
Weight of gas[1] (lb.)	1,949
Sludge wasted (cu. ft.)	118
Sludge in storage (cu. ft.)	117
Vol. sol. in wasted sludge (lb.)	162
Vol. sol. in stored sludge (lb.)	56

Vol. Sol. to Digester (lb.)	Vol. Sol. Accounted (lb.)		
2,664	In effluent	601	
	In gas	1,949	
	In wasted sludge	162	
	In stored sludge	56	
		2,768	
	Unaccounted	−104	= +3.9%
2,664		2,664	

[1] At 0.056 lb. per cubic foot.

Sludge to Be Disposed

Period No. 5 made it possible to make some calculation of the sludge to be disposed, as follows:

Total feed of raw sewage (cu. ft.)	33,045
Total sludge pumped to storage (cu. ft.)	235
Total sludge wasted (cu. ft.)	118
Total sl. rem. in storage, at 1.42% T.S. (cu. ft.)	117
Volume of 117 cu. ft. reduced to 4% T.S. (cu. ft.)	41.6
Total sludge, 4% T.S., to be disposed of (cu. ft.)	159.6
Total sludge to be disposed of (% of raw sewage)	0.48

It is believed that this 4 per cent T.S. sludge can be disposed of at a higher rate of solid. On standing over night at room temperature, a separation of ⅔ sludge on top and ⅓ water on the bottom of the glass container was noted.

Clarifier Performance

The amount of sludge being returned from the clarifier to the digester amounts to 60 per cent of the total influent flow.

Suspended solids determinations are taken daily on the influent and effluent of the clarifier. Knowing the quantity of raw feed and returned sludge metered into the system, the suspended solids in the returned sludge can be calculated. The calculations of Table VIII are typical of the method used in arriving at the suspended solids in the returned sludge.

Numerous calculations show the suspended solids at 1.6 per cent.

Efforts to increase the concentration of the solids in the return sludge by reducing the amount pumped back have been unsuccessful, largely because the sludge is removed hydraulically and the sludge drawoff tubes are only 1¼ in. in diameter. The sludge thickens to such an extent that the flow progressively reduces to zero. It is hoped to correct this by installing variable-speed pumps on these sludge lines.

Cost of Vacuum

The present pilot plant appropriated one of the Duriron ejectors that were available and had formerly been used

TABLE VIII.—Method of Calculating Return Sludge Suspended Solids

Sample No.	Total Raw Feed (cu. ft.)	Total Feed (cu. ft.)	S.S. in Clarifier Influent (p.p.m.)	S.S. in Clarifier Effluent (p.p.m.)	Total Feed Disposal		S.S. in Return Sludge
					Effluent (%)	Ret. Sl. (%)	
777	1,000	2,482	9,660	18	40.3	59.7	16,200
778	920	2,446	10,080	30	37.6	62.4	16,200
779	1,020	2,368	9,240	14	43.0	57.0	16,200
780	1,680	4,126	9,080	19	40.7	59.3	15,200
781							
782	980	2,554	9,140	8	37.4	62.6	14,600

to draw chlorine from 1-ton containers. The rated capacity of the ejector is 100 to 125 g.p.m. Although of cast construction and lacking the efficiency of a well-designed and machined ejector, the present unit is more than sufficient for the pilot plant. However, operation of a vacuum pump on a full-sized plant might require considerable power.

Tests were run to determine this cost. As the power required would be proportional to gas to be removed at the pressure of 25 to 26 in. of vacuum, the following method was used to determine this.

A manometer and valve were installed on the vacuum line of the system. The height of the liquid in the vacuum detention tank was noted, as well as the manometer reading. By closing the valve on the vacuum line and allowing the feed to continue through the system, the drop of level in the tank should be proportional to the gas being removed. At the end of 3 min. the reduction of head in the vacuum detention tank was noted, as well as the manometer reading. By calculating the volume noted back to the initial pressure, some idea of the volume of gas being removed per minute is obtained. This procedure assumes that the system is tight. Before starting the system all joints were sealed and new valves were used. When placed under a 25-in. vacuum and closed off, there was not more than 1 in. drop in vacuum overnight. The calculations used in these tests were as follows:

Barometer reading (in. Hg) 29
Vacuum at start (in. Hg) 26
Vacuum after 3 min. (in. Hg) 25.25
Abs. pressure at start (in. Hg) 3
Abs. pressure after 3 min. (in. Hg) 3.75
Volume of gas space under vacuum at start (cu. ft.) 15.1
Increase in gas vol. due to level drop in 3 min. (cu. ft.) 2.0

Total vol. at 3.75 in. Hg = 15.1 + 2.0 = 17.1 cu. ft.
Final vol. if at constant of 3 in. Hg
Volume at 3 in. Hg = $17.1 \times 3.75/3$ = 21.4 cu. ft.
Original volume = 15.1 cu. ft.

Increase in vol. at 3 in. Hg in 3 min. = 6.3 cu. ft.
Gas release rate = 2.1 c.f.m. at 3 in. Hg
Av. rate of raw feed during test = $\frac{3}{4}$ c.f.m.
Av. rate of raw feed for 1 m.g.d. = 93 c.f.m.

$$\text{Gas release rate for 1 m.g.d.} = \frac{2.1 \times 93}{0.66} \text{ at 3 in. Hg}$$

= 296 c.f.m. at 3 in. Hg

A single-stage vacuum pump with piston displacement of 400 c.f.m. requiring 20 hp. is needed for 1 m.g.d. of raw feed if the need is constant throughout the day. Assuming a combined motor and drive efficiency of 83 per cent, the power demand would be 18 kw. annually and consumption would be slightly under 160,000 kw.-hr. annually. The power cost would then be $1,600 annually at an energy charge of $0.01 per kw.-hr.

The test results, actually an average for four tests, show that about 20 to 30 per cent of the total gas production was removed through the vacuum system.

It is also interesting to note that when the gas removed by the vacuum was taken into consideration a remarkably close check in volatile solids balance was obtained.

Sludge Characteristics

As the sludge comes from the digester it is heavily charged with gas. Under quiescent conditions it either will all come to the top or some will go to the top and some to the bottom. When the sludge is very active, as is the case when it is being fed a strong waste, it will all quickly rise to the surface.

After the vacuum treatment the sludge settles rapidly and remains down for 1 to 3 hr. The removal of the gas from the sludge increases its density so much that it settles rapidly. The influent end and effluent end of the clarifier look equally clear.

The clarifier gives good separation with the sludge occupying two-thirds of the depth of the clarifier. Above this level, gasification of the bottom sludge causes some turbulence. If the sludge is not removed, it builds up to the level of the effluent weir and escapes.

This sludge seems to exhibit distinct thixotropic properties. Unless it is moving, there is a tendency for it to congeal.

Under conditions of rapid gas production the sludge seems to bulk and requires more pump-back to maintain a satisfactory sludge level in the digester.

Elutriation with weak wastes seems to improve the settleability. This is demonstrated by night and week-end performance, when the raw waste is weaker.

Filtration of Anaerobic Effluent

To check the amenability of the anaerobic effluent to further aerobic treatment, a portion was treated over a barrel-sized rock filter. An organic loading of 2,300 lb. per acre-foot per day and a volumetric loading of 8.0 m.g.a.d. was used. This gave removals of 50 per cent of the 5-day B.O.D.

It has been stated that the somewhat lower removal might be accounted for by the fact that the most readily removable organic matter had been taken out by the filter.

Nitrogen Changes in Digestion

Comparatively small amounts of nitrogen were removed by the anaerobic process. Table IX is typical of the performance of digestion on the nitrogen content. Although the removal of organic nitrogen is high, it is apparent that the transformation is from organic to inorganic. This is apparent by the progressive increase of alkalinity in the effluent.

There would be no advantage in oxidizing this ammonia to nitrate on a filter, as the one form of nitrogen would be just as effective as a fertilizer for algae propagation as the other.

TABLE IX.—Effect of Anaerobic Digestion on Nitrogen Content, Period 5

Item	Total N (lb.)	NH_4-N (lb.)	Org. N (lb.)
Raw sewage	146.8	31.9	114.8
Anaerobic effl.	122.9	114.7	8.10
Removal (%)	16.3	−260.0	93.0

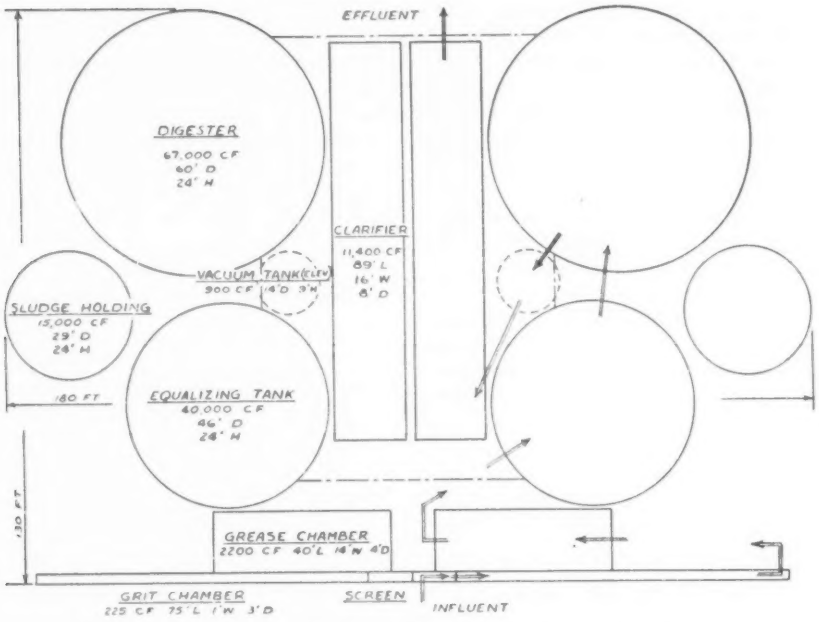

FIGURE 4.—Suggested layout for 1-m.g.d. anaerobic process plant for treating packinghouse wastes.

If the anaerobic effluent or the filter oxidized effluent would discharge into a lake, there might be excessive growth of algae. If discharged into a stream where progressive dilution occurs, the algae growth might not be a problem.

Economic Considerations

Economic advantages in construction and operation seem to be indicated in the anaerobic method of treating packinghouse wastes. Savings of 35 to 50 per cent in construction costs and 15 to 25 per cent in operation have been predicted, as compared with the aerobic method of sedimentation and filtration with comparable B.O.D. removals. The costs used in comparing the two processes reflect present bidding at an *Engineering News-Record* construction cost index of approximately 550.

Compactness of Design

Figure 4 shows a plan for a plant capable of handling 1 m.g.d. The plant consists of grit chamber, equalizing tanks, digesters, clarifiers, vacuum system, sludge storage, and control building. No provision is made for sludge disposal, which in the case under discussion would be done by hauling to dumping grounds. The area required for the plant shown is slightly less than 0.5 acre.

If the equalizing tanks are used for the dual purpose of equalizing and digestion, the plant could handle 1.5 m.g.d. There is some evidence that the present pilot-plant digester can take a higher rate of feed during daytime operation.

Summary

1. Packinghouse wastes seem to be peculiarly adapted to anaerobic digestion, because thermal and mineral requirements are intrinsically present.

2. Packinghouse wastes of a wide range of concentration can be digested with a detention time of 24 hr. or less.

3. B.O.D. removals of 95 to 96 per cent can be obtained.

4. Volatile solids loadings of the digester from 0.061 to 0.081 lb. per cu. ft. per day have been demonstrated.

5. B.O.D. loadings of the digester ranging from 0.067 to 0.084 lb. per cu. ft. per day have been recorded.

6. A practical method of continuously removing entrained gas from the digester effluent by vacuum is described.

7. An optimum ratio of culture to substrate has not been demonstrated.

8. The maximum B.O.D. loading of the digester has not been established.

9. The anaerobic effluent is amenable to further aerobic treatment, if necessary.

10. A nominal amount of sludge will be produced for disposal.

11. The anaerobic method seems to offer economic advantages, both in construction and operating costs.

12. The anaerobic method lends itself to compactness of design.

NEW MATERIALS CONTROL SYSTEM

A new materials control system limited to assuring deliveries of enough steel, copper, and aluminum for the Department of Defense and the Atomic Energy Commission was recently announced by the National Production Authority. The Defense Materials System is expected to take effect July 1, following the June 30 expiration of the more embracing Controlled Materials Plan.

Under the new Defense Materials System only military and AEC orders having defense program symbols will be controlled, from original mill allotments, and controls and program assistance will be removed from civilian production and construction beginning with third-quarter requirements. Effective as of March 23, 1953, controlled materials producers were authorized to accept unrated orders for steel, aluminum, and copper for delivery after June 30. Directives have been issued, however, providing for authorized controlled materials orders accepted for shipment prior to July 1, 1953, and carried over into the third quarter to be given preference over new unrated orders requesting delivery in the third quarter.

Not included in the general freeing of materials from control are the nickel-bearing stainless steels, for which there is a continuing heavy military demand.

REDUCTION OF PLATING WASTE LOSSES BY RECLAIM TANKS *

By C. F. Hauri

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In previous papers (1)(2) it was shown that Delco-Remy Division of General Motors Corporation, located at Anderson, Ind., approaches the problem of cyanide contamination of sewer waters in two ways, as follows:

1. Mechanical methods, whose procedures attempt to reduce the amount of cyanide reaching the sewer effluent.
2. Chemical methods, which decompose the cyanide to harmless compounds before the effluent flows from the property.

It is the first of these methods with which this paper deals, concerning itself only with cyanide problems relating to plating processes.

Source of Cyanide Wastes

The source of cyanide contamination from plating operations is in the rinsing of the electrolyte from articles processed in cyanide plating solutions.

An adequate reclaim program for these solutions is undoubtedly the greatest single procedure that will reduce the cyanide content of rinsing waters by mechanical means. Reclaim programs also have the advantage of economy, as the reclaimed solutions are used to replenish evaporation and dragout losses in the plating bath. It is a matter of policy at Delco-Remy to keep all cyanide possible from the sewer and to destroy the balance.

To alleviate a disposal problem it is necessary to eliminate at the source as much of the contaminant as possible. Here, also, the greatest economic returns can be made, and it is safe to say, "The more kept from the effluent, the less to destroy." No single item will do as much to keep the cyanide content of the rinse waters to a minimum as a good mechanical reclaim program. Obviously, where evaporation losses are high, this is easily done. When a solution is operated at room temperature, however, evaporation losses are likely to be small. Hence, conditions are much less favorable for utilizing a reclaim program in conjunction with cadium- and zinc-plating baths, which operate at 90° F. Additional difficulty is encountered with reclaims in automatic equipment, because dragin approximately equals dragout.

Automatic Plating Equipment

The principal cyanide plating process performed at Delco-Remy is zinc-plating, 90 per cent of which is done in automatic equipment. Both rack and barrel equipment is used, the barrel equipment handling the largest percentage of production. Figure 1 shows one of six barrel machines in operation in the Division's plants.

The machine is essentially a conveyor mechanism mounted above suitable processing tanks used in plating. The conveyor mechanism automatically transfers the work carriers, called "baskets," through all the steps of the plating operations. The forward movement of the machine is intermittent, each basket rotating in the same place for a prearranged time. All transfers are then made automatically forward to the next station.

* Presented at 27th Annual Meeting, Michigan Sewage and Industrial Wastes Assn.; Traverse City, Mich.; May 19–21, 1952.

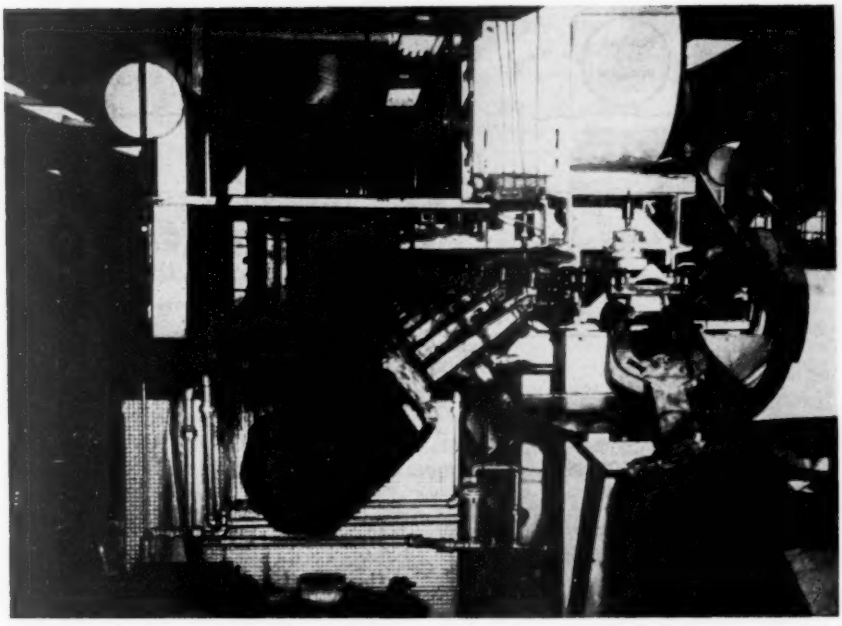

FIGURE 1.—Automatic barrel machine for plating, showing baskets on conveyor line (center) and ventilating provisions (left and right overhead).

To give some idea of the capacity of these machines, each basket holds from 20 to 25 sq. ft. of surface area, the baskets being processed at the rate of one per minute. This approximates a maximum of 1,500 sq. ft. plated per hour per machine.

The plating baths operate at 90° F. and are of the following approximate composition:

Chemical	Conc.
Sodium cyanide	16 oz. per gal.
Zinc	5.5 oz. per gal.
Caustic soda	13 oz. per gal.

It can be surmised that without an adequate reclaim program the dragout losses would be great and the cyanide destruction program would be a large undertaking.

Reclaim Methods

In attempting to use reclaim stations it was found that only a small portion of the reclaimed solution could be added back to the plating bath, due to the previously mentioned dragin. Consequently, it was necessary to find a way to use the reclaimed solutions. This could only be done by minimizing the dragin, as operation of the plating baths at higher temperatures is detrimental.

The dragin was kept to a minimum by tumbling the work in an empty station preceding plating (see Figure 2). Consequently, the reclaimed solutions could be added back to the plating bath more frequently.

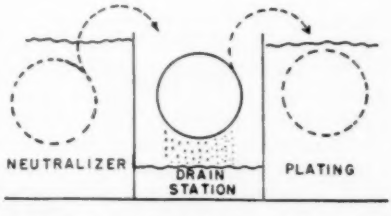

FIGURE 2.—Dragin is minimized by tumbling the work in an empty station preceding plating.

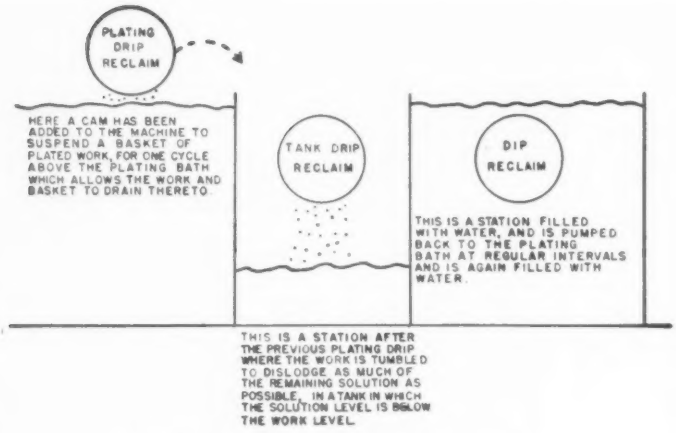
PLATING DRIP RECLAIM
HERE A CAM HAS BEEN ADDED TO THE MACHINE TO SUSPEND A BASKET OF PLATED WORK, FOR ONE CYCLE ABOVE THE PLATING BATH WHICH ALLOWS THE WORK AND BASKET TO DRAIN THERETO.
TANK DRIP RECLAIM
DIP RECLAIM
THIS IS A STATION FILLED WITH WATER, AND IS PUMPED BACK TO THE PLATING BATH AT REGULAR INTERVALS AND IS AGAIN FILLED WITH WATER.
THIS IS A STATION AFTER THE PREVIOUS PLATING DRIP WHERE THE WORK IS TUMBLED TO DISLODGE AS MUCH OF THE REMAINING SOLUTION AS POSSIBLE. IN A TANK IN WHICH THE SOLUTION LEVEL IS BELOW THE WORK LEVEL.

FIGURE 3.—Three types of reclaim operations.

A special terminology has been applied to various reclaim patterns. Figure 3 shows three types of reclaims.

Although any one of these reclaim cycles is of considerable benefit in cyanide reclaim problems, a combination is worthwhile. This is demonstrated by the values shown in Figures 4 and 5, which give results of tests made on production runs of some of the Delco-Remy machines operated with various reclaim systems. All types of parts, varying considerably in size and shape, were run during these tests. Three separate tests were made and averaged. Figure 4 shows what can be expected without a reclaim program—1.62 oz. NaCN per basket, or 6 lb. NaCN per hour to waste—an enormous amount. Figure 5 gives the results of experiments made with various types of reclaim programs. By having the basket drip over the plating tank for 1 min., or one cycle, an average of 0.45 oz. NaCN per basket is reclaimed directly to the plating solution and is 28 per cent of the total dragout.

By transferring the basket to an empty station, or tank drip wherein it rotates for one cycle, an average of 0.3 oz. NaCN per basket is further reclaimed. This must be pumped back to the plating bath with such frequence as necessary to prevent baskets from dipping into the solution. This station represents 18.5 per cent of the total.

The next station is a tank filled with water, and is called a rinsing or dip reclaim. In the production run an average of 0.64 oz. NaCN per basket is ad-

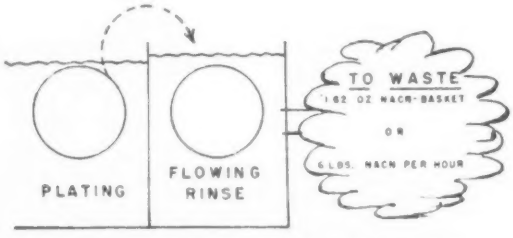

FIGURE 4.—Cyanide wasted without reclaim.

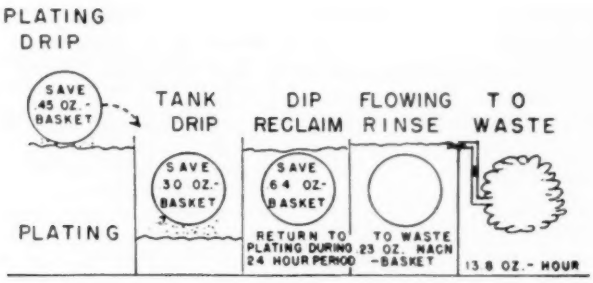

FIGURE 5.—Cyanide wasted with reclaim, giving 86 per cent recovery.

ditionally reclaimed. Current procedure is to pump this reclaim solution back to the plating bath every day to maintain the proper level. This station is again filled with water and the cycle repeated. Here 39.5 per cent is accounted for, or a total of 86 per cent recovery.

The saving that can be effected in a cyanide destruction program by using these reclaim systems is shown in Table I. This amounts to $1.22 per hour in the conversion to cyanates and $3.04 per hour when the cyanide is totally destroyed. This shows the economies of "the more saved the less to destroy."

Process Adaptable to Other Equipment

This work with an automatic plating machine can be considered as an example. Comparable results can be obtained with other processes and equipment. These systems are also used in horizontal barrel and automatic rack plating equipment in the Delco-Remy plants.

Ingenuity and thought must be exercised in adapting machines in which insufficient after-plating equipment was provided. The installation of a cam to suspend the basket over the plating tank will, of course, take one cycle from the plating time. This can often be compensated for by increased current densities during plating.

TABLE I.—Savings ($ per Hr.) in Cyanide Reduction by Alkali Chlorination with Reclaim Operation

Operation	Red. to Cyanates	Red. to Completion
Without reclaim	1.42	3.50
With reclaim	0.20	0.46
Savings	1.22	3.04

A tank can be made to fit inside the plating tank by welding a steel section, or if the plating tank is Koroseal lined, by sinking a complete tank. This will add a reclaim station, but is again subject to limitations of plating time and power capacity.

Experiments are proceeding to further improve the efficiency of mechanical reclaim systems and some of the experiments may be of interest. One is the addition of a drip station after the dip reclaim, as shown in Figure 5. This station will recover 78 ml. of solution that is at present going to the flowing rinse. It also has been found that there is more total reclaimed solution than can be added back to the plating bath daily.

Another thought that was proposed, was to add back through the first plating drip (Figure 5) approximately 100 ml. of solution from the dip reclaim through a high-pressure spray. This 100 ml. would in some way be fairly accurately determined and added to each basket in the drain position. It is hoped that this procedure will be advantageous to the plating drip station by the action of dilution and to also

keep the dip reclaim at a minimum cyanide concentration.

It is obviously more desirable to spend the small amount of money necessary to reduce the quantity of cyanide to be destroyed, rather than to spend the larger amount of money required to destroy the large amount of cyanide that would otherwise be present.

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FISH KILLS BY INDUSTRIAL POISONS

In a recent 4-page leaflet entitled "Industrial Poisons Destroy a Resource," the Washington Pollution Control Commission makes an appeal to all industry in that state to carefully control disposal of waste substances, particularly if of a poisonous nature.

The appeal is backed up by citation of five recent instances of known discharges or dumpings of extremely poisonous waste materials into state waters. Four of the events resulted in disastrous and unnecessary destruction of fishery resources, as follows:

1. On September 13, 1952, just outside of Commencement Bay, Tacoma, an estimated 3,000 silver salmon were destroyed by dumping of some unusual poisonous material, probably from some industry in the city industrial area. Although the actual value as fish may not have exceeded $5,000, as prime rearing stock on the way to spawning beds they were worth more than $100,000 by a Fisheries Department estimate.

2. On November 3, 1952, a much greater kill occurred in the Green River below the Kent municipal sewer outfall. This kill was caused by the dumping into the city sewers of a small amount of highly poisonous material. More than 10,000 silver salmon, 50 chinooks, and many thousand fingerlings were destroyed. As rearing stock the larger fish were valued in excess of $500,000.

3. Dumping of pentachlorphenol at Chehalis on December 9, 1952, caused destruction of from 500 to 700 adult silver salmon and steelhead trout, some of which were 30 in. long. Again, the fish were spawning stock and of considerable value.

4. In Growmore, Yakima County, an apple warehouse dumped a washer containing about 300 gal. of 0.6 per cent sodium-σ-phenylphenate, causing destruction of fish for a mile or more in Wide Hollow Creek. This is a compound typical of a considerable number of recently developed commercial materials for the control of molds, insects, and other organisms.

5. In Tacoma Harbor on December 12, 1952, while unloading drums of cyanides from a ship, a broken drum was dumped into the waters of the bay. The 300 lb. of highly poisonous material involved could cause damage that may never be determined.

SPRAY IRRIGATION OF FOOD PROCESSING WASTES *

By Joseph M. Dennis

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In recommending adequate treatment facilities for small industries throughout Tennessee, the State Department of Health is often confronted with the situation in which the cost of the treatment plant will exceed the total investment of the food processing plant itself. For the industrialist to look with favor toward the stream pollution control program, the cost of treatment facilities should be small enough so that he will not be at an economical disadvantage in competing with those fortunate enough to have access to city sewers or those located near larger streams furnishing adequate dilution water and requiring only screening of the waste before final discharge.

Many food processing plants are located in small villages and towns financially unable to build treatment plants large enough to accommodate both the industrial waste and domestic sewage, especially since in many cases food processing plant production is subject to wide seasonal variations.

Many of the small streams in Tennessee go completely dry in the hot summer months or have only a limited flow. Nuisances are created immediately below food processing plants located on these small streams. Objectionable odors emanate from the streams and large amounts of organic material may either float on the stream surface or be laid down as thick sludge deposits. These materials during their stabilization use up all the oxygen resources of the stream and thus destroy all aquatic life except for the benthos biota. The sludge deposits are often flushed out during flash rain storms and cause severe pollution farther downstream, this pollution sometimes being introduced into the lower reaches of streams that are known to be excellent fishing waters. Some of these same streams pass through valuable farm lands and are used for stock watering or the stream may pass through built up residential areas. In such instances it is easy to see that treatment facilities not effecting maximum removal of organic pollutants can not be considered adequate.

Wastes Must Be Fresh

Use of spray irrigation for the watering of crops has been known for many years, but the value of this method as a means of disposing of food processing wastes has only recently been recognized. This method of disposal would solve the stream pollution problem for many food processors during the critical months of the year, providing adequate land is economically available. Objectionable odors may be given off by the spray irrigation system if the waste is first passed through settling units and allowed to become septic. When the wastes do not contain appreciable amounts of settleable material, however, they may be sprayed directly on the land before noticeable odors are developed.

Early Applications

The first reported application of spray irrigation was inaugurated in 1947, at the Hanover Canning Company, Hanover, Pa. The operation of this combined lagoon and irrigation

* Presented at 1952 Annual Meeting, Kentucky-Tennessee Industrial Wastes and Sewage Works Assn.; Knoxville, Tenn.; Sept. 15–17, 1952.

system solved completely the problem of stream pollution for that company. In 1949 the Seabrook Farms, Seabrook, N. J., resorted to this method of disposal for their entire volume of waste. During 1951 as many as 22 additional spray irrigation systems were placed in operation throughout Wisconsin, Michigan, Minnesota, New Jersey, Iowa, Maryland, and Pennsylvania.

In 1949 spray irrigation of milk processing waste was initiated at the Swiss Farms, Donelson, Tenn. This system has been in continuous service for the past three years and has been entirely satisfactory from every viewpoint. Recently the Pet Milk Company in Athens, Tenn., has used this method for the disposal of its milk waste while the company was finishing a modern industrial waste treatment plant.

Spray *vs.* Furrows

Spray irrigation is best adopted to areas where the terrain is generally rolling. In flat areas furrow irrigation has been used extensively. When furrow irrigation can be used it may be preferred to spray irrigation, inasmuch as the initial outlay for extensive lateral piping is not required. This method, however, requires constant supervision by personnel familiar with the principles of land irrigation so as to prevent flooding out of furrows and thus causing undue soil erosion.

Costs

The costs of spray irrigation for a particular food processing plant can not be given here as they vary over a wide range depending upon a) variation in land values, b) differences in soil absorption rates, c) variations in waste strengths, d) proximity of the processing plant to the disposal area, and e) differences in pumping heads. A recent article (1) described a spray irrigation system for a Minnesota pea and corn cannery, which utilized a 110-acre farm for the disposal of 30 m.g. of waste from a pack of 366,000 cases of peas and corn. The total cost of this plant's operations, including a 15-yr. amortization period, only added $0.006 to the cost of each case of peas or corn.

Before a spray irrigation system is built the services of a competent engineer should be obtained to make a study of the local industrial waste problem, on the basis of which he can design the needed units as required, often saving the food manufacturer many dollars and headaches. Sometimes it has been found more economical to pump the wastes several miles from the food processing plant than to use standard waste treatment methods. The costs of spray irrigation systems are often less than for lagoon construction with the added cost necessary for successful odor control.

Crop Selection Important

The cover crop on the disposal area is a very important part of the spray irrigation system. It has been found that the best absorption and the least runoff is obtained from a well-established pasture or on fields with dense grasses or weed crops. Soil without a cover crop will absorb only half as much water as when it is properly protected by vegetative cover. Spray dropping on bare soil tends to compact the upper layers and make the soil less absorbent. It has been suggested that deep-rooted crops, such as alfalfa, may not tolerate as heavy applications of water as shallow-rooted grasses.

Waste from canneries and meat packing plants should be screened before pumping to spray irrigation fields. It has been reported that this is the greatest single operational difficulty in the spray irrigation system. The larger particles of waste will settle in the piping system and may clog the relatively fine openings of the spray nozzle. Screens are usually of the 20-mesh size and may consist merely of a feed sack hung over the waste discharge line

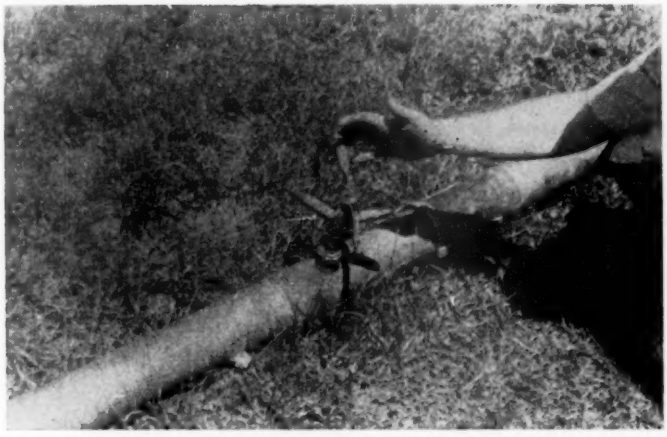

FIGURE 1.—Typical nozzle and portable aluminum piping suitable for spray irrigation of industrial wastes.

from the plant, or be of elaborate design, such as the stainless steel vibrating type. Wastes from milk processing plants require only a minimum of screening, since most of the milk solids in the wastes are finely divided.

It should be pointed out that in areas where freezing weather is encountered a pump suction well or some other storage reservoir should be provided that will accomodate the entire flow of the waste until a time when the ground has thawed.

Swiss Farms Study

The only complete report on a spray irrigation system in Tennessee is that of the Swiss Farms previously mentioned. During 1950 a study was made of the wastes from this dairy to ascertain the quantity and strength of wastes that were being disposed of on a 2-acre pasture seeded with 2 lb. of fescue and 0.1 lb. of clover. In collecting a representative sample to be analyzed, the State Health Department representative took an equal portion of the waste during each 15-min. period of pump operation. At the end of the day's operation this composited sample was analyzed and found to contain 660 p.p.m. of 5-day B.O.D. A record was kept of the time the pump was operating, by which it was found that 12,650 gal. of water had been disposed of by the spray irrigation system during the sampling period. Using the strength of the wastes and this quantity of flow it was calculated that 69.6 lb. of 5-day B.O.D. were applied to the disposal area during the day. As a comparison, this is considered to be equivalent to the organic materials found in the sewage from a community of 420 persons.

The spray irrigation system at the Swiss Farms consists of a small sump and pressure control switch, a centrifugal pump driven by a 5-hp. electric motor, scrap galvanized 2-in. pipelines to the pasture area, and spray nozzles (Figure 1) fitted at 100-ft. intervals. Only two nozzles of the spray system are used at a time. It requires only a few minutes for one attendant to change these sprays each morning. The entire two acres are covered once every ten days.

The owner of the Swiss Farms estimated that the entire system could be duplicated for about $500. During a visit to the Swiss Farms on June 10, 1952, a luxuriant forage crop (Figure 2) was noted to be growing on the 2-acre disposal field, which otherwise

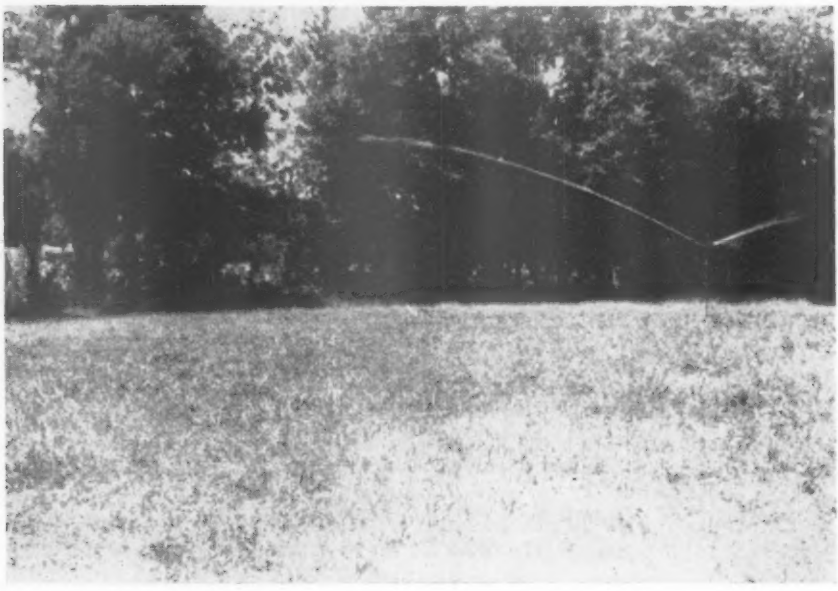

FIGURE 2.—Luxuriant forage crop resulting from irrigation with milk waste during drought period.

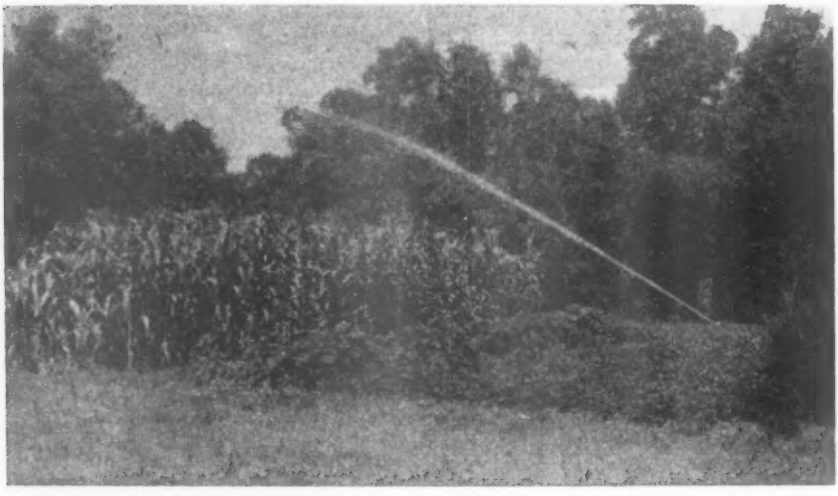

FIGURE 3.—Vegetable garden shows effect of irrigation with milk waste, the corn in the center of the row, where it receives more waste spray, being noticeably taller than at either end.

would have been little more than barren waste land during the drought of 1952. A small vegetable garden also is irrigated with these wastes (Figure 3).

It is realized that this method of food processing waste disposal has certain limitations and cannot be adopted by all food processors. All of the recorded information on spray irrigation concerns the disposal of vegetable cannery wastes; there is no record of milk waste disposal other than the two as mentioned in Tennessee. Spray irrigation recently was recommended as an alternate method of disposal for a chicken slaughterhouse. It is conceivable that this method of waste disposal may be extended to other rural slaughterhouses within the near future.

Spray irrigation of food processing waste is relatively new and application rates have not been established for all types of food processing wastes. A need is indicated for some controlled projects that could be studied jointly by the agricultural experiment stations and the engineering departments of universities to properly evaluate many of the variables previously mentioned herein. Opportunities for basic research in this field are indeed abundant.

Acknowledgments

Much of the material for this paper was obtained from N. H. Sanborn of the National Canners Association and E. R. Niederhauser of the Swiss Farms, Donelson, Tenn.

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NUTRITIONAL REQUIREMENTS IN THE BIOLOGICAL STABILIZATION OF INDUSTRIAL WASTES

IV. Treatment on High-Rate Filters *

By Harold D. Kilgore, Jr.,† and Clair N. Sawyer

Department of Sanitary Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

The significance of nutritional considerations in biological stabilization of industrial wastes is becoming well recognized. Very little information exists on the actual requirements during treatment on trickling filters. Since such units are of great value in the treatment of many industrial wastes, it seems appropriate to obtain basic information on their requirements.

Considerable fundamental and applied research has been done on various aspects of the nutrition theory as applied to the activated sludge process. Early investigations were reported by Sawyer (10)(11)(12), while more recent studies have been presented in previous articles of this series (3)(4)(5). Due to the simplicity of the equipment required for research on the fill-and-draw activated sludge process, and to the comparative ease with which temperature control can be accomplished, the process lends itself admirably to controlled studies.

On the other hand, the complexity, cost of equipment, and large volumes of wastes required for controlled research on trickling filters has mitigated against their use in laboratory-scale studies. Therefore, confirmed data on the nutritional requirements of this method of treatment, as well as many other basic variables affecting performance, are meager.

The studies of Wattie (13), Butterfield and Wattie (1), and Goldthorpe (2), have demonstrated that, qualitatively speaking, the predominant bacteria of standard trickling filter slimes are not only similar to those in the floc of activated sludge, but also that the floc and slime are interchangeable in the activated sludge process. Furthermore, Heukelekian (6)(7)(8)(9) has shown that the nature of the slimes obtained from a high-rate filter (biofilter) and standard-rate filter were quite similar, differing mainly in quantitative aspects.

Hence, it has been reasoned that, if the nutritional requirements of the activated sludge process and the high-rate trickling filter can be shown to be similar under comparable conditions of temperature and loading, considerable time and expense might be saved by making preliminary laboratory investigations on the fill-and-draw activated sludge process, since the results of such studies could then be translated directly to trickling filter operation.

Objectives

The purposes of this investigation were three-fold:

1. To ascertain the quantities of nitrogen and phosphorus that are used per unit of B.O.D. applied to high-rate trickling filters when such filters are fed industrial waste-domestic sewage mixtures containing nitrogen and phosphorus in excess of metabolic requirements. Such data should be of interest to those concerned with treatment of industrial wastes in conjunction with domestic sewage.

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2. To compare the nutritional requirements of the high-rate trickling filter with those of the activated sludge process, to determine whether the results obtained by one process are applicable to the other, under comparable conditions of temperature and loadings.

3. To ascertain variations in high-rate trickling filter efficiency at various ratios of B.O.D. to nitrogen and phosphorus when less than optimum amounts of nitrogen are supplied. Such data will be of value to those concerned with the design and operation of trickling filter plants for the treatment of wastes deficient in nutrients.

Industrial Wastes and Domestic Sewage

Of the industrial wastes studied in the course of this research, cotton kiering liquor and rag-rope pulp cooking liquor have been described previously (4). The cotton bleachery waste was obtained from the equalization tank of the waste treatment plant of a nearby bleachery.

All wastes were obtained in large quantities and stored at room temperature in the alkaline condition, except for the bleachery waste, which was kept under refrigeration. In all cases, the pH of the waste was adjusted to the range 7 to 8 before use.

The domestic sewage was procured on alternate days from the Ward Street pumping station, Boston. The sewage was settled and fine screened before using or storing under refrigeration for subsequent use.

Experimental Method

The first paper of this series (3) relates the details of the experimental methods employed for the activated sludge and trickling filter studies. To summarize, the trickling filters consisted of two-stage, high-rate, 3-ft. deep units operated at room temperature (25 to 30° C.) at daily B.O.D. loadings ranging from 0.3 to 0.7 lb. per square foot or 50 to 116 lb. per 1,000 cu. ft. of filter volume. Final effluent was recirculated to the primary dosing siphon.

Fresh feed mixtures were prepared every 8 to 12 hr. and added to the feed supply tanks, which were gently agitated by slow-speed stirrers. The feed mixtures and effluent used for recirculation were pumped by a rotary, positive displacement pump.

Three different two-stage filters were used during the course of the work. The first filter used contained 1½- to 2½-in. rock and is referred to as filter A. Later two filters were constructed of the same design as filter A, but with certain improvements. These filters contained 2- to 3-in. rock and are referred to as filters B and C.

Industrial Waste-Sewage Mixtures

The first investigations were made on mixtures of domestic sewage and industrial wastes, the sewage in all cases supplying nitrogen and phosphorus in excess of metabolic requirements. The results shown in Tables I and II should be of importance to operators of municipal treatment plants receiving substantial contributions of industrial wastes.

Except in the case of the relatively weak bleachery waste-sewage mixture, which was applied at the rate of 230 g.p.d. per square foot, the waste-sewage mixtures were applied at the rate of 115 g.p.d. per square foot. B.O.D. loadings varied from 0.30 to 0.42 lb. per square foot per day. Removal of B.O.D. was consistently good, with slightly better results on filter A than on filters B and C, in which a larger rock was used.

Table II summarizes the nitrogen and phosphorus requirements of the waste-sewage mixtures. These data demonstrate that requirements for nitrogen vary somewhat for different wastes, but a value of about 5.5 lb. per 100 lb. of B.O.D. removed would serve

TABLE I.—Treatment of Industrial Wastes-Sewage Mixtures; Experimental Conditions and Process Efficiency

Run No.	Waste	Volumetric Data				B.O.D.				Temp. (°C.)	Filter No.
		Waste (%)	Recir. Ratio	Feed Rate[1] (g.p.d./ sq. ft.)	Appl. Rate[1] (g.p.d./ sq. ft.)	Load[2] (lb.)	Feed (p.p.m.)	Effl. (p.p.m.)	Rem. (%)		
I	Bleachery waste	22	1:1	230	460	0.32	164	11	93.5	27	A
II	Cotton kiering	10	3:1	115	460	0.41	426	7	98	29	A
III	Cotton kiering	10	5:1	115	690	0.38	392	9	98	28	A
IV	Rope and rag pulp cook	1	5:1	115	690	0.30	313	4	98	28	A
V	Rope pulp cook	4	3:1	115	460	0.39	406	37	91	26	A
VI	Rope pulp cook	4	5:1	115	690	0.42	435	21	95	28	A
VII	Cotton kiering	10	3:1	115	460	0.41	430	21	95	29	B
VII	Cotton kiering	10	3:1	115	460	0.41	430	37	91.5	29	C

[1] 115 g.p.d. per sq.ft. = 5 m.g.d. per acre.
[2] Pounds per square foot per day; 0.138 lb. per sq. ft. per day = 1,000 lb. per acre-ft. per day for a 6-ft. filter or two 3-ft. filters in series.

for preliminary calculations. Phosphorus requirements varied quite radically, with a high of 1.25 lb. and a low of 0.36 lb. per 100 lb. of B.O.D. removed. A reasonably safe value to use in preliminary calculation would appear to be 1.0 lb. per 100 lb. of B.O.D. to be removed.

Activated Sludge *vs.* Trickling Filters

A comparison of the nutritional requirements during trickling filter and activated sludge treatment of various wastes is given in Table III. These data show the nitrogen requirements of the high-rate trickling filter to be as great or possibly slightly greater than activated sludge. The B.O.D. loadings on the filters were somewhat greater than used in the activated sludge studies. This would tend to increase metabolic synthesis and give slightly higher nutritional requirements. Therefore, it may be concluded that the nitrogen requirements for treatment on high-rate filters are comparable to those for treatment by activated sludge and results obtained by studies using the latter may be translated directly to trickling filters, provided loadings are comparable.

The data showing phosphorus re-

TABLE II.—Nitrogen and Phosphorus Requirements for Stabilization of Waste-Sewage Mixtures

Run No.	Waste		N Requirements		P Requirements	
	Type	%	Ratio[1] B.O.D./N	Lb. N per 100 lb. B.O.D. Rem.	Ratio[2] B.O.D./P	Lb. P per 100 lb. B.O.D. Rem.
I	Bleachery	22	15.8	6.3	80	1.25
II	Cotton kiering	10	17.0	5.9	110	0.91
III	Cotton kiering	10	18.8	5.3	96.5	1.04
IV	Rope and rag pulp cook	1	13.5	7.4	166	0.60
V	Rope pulp cook	4	19.2	5.2	277	0.36
VI	Rope pulp cook	4	25.2	4.0	262	0.38
VII	Cotton kiering	10	19.0	5.3	169	0.59
VII	Cotton kiering	10	19.3	5.2	200	0.50

[1] Ratio of B.O.D. removed to nitrogen utilized.
[2] Ratio of B.O.D. removed to phosphorus utilized.

TABLE III.—Comparison of the Nutritional Requirements of the High-Rate Trickling Filter and the Activated Sludge Process in the Treatment of Waste-Sewage Mixtures

Item	Bleachery Waste and Domestic Sewage		Kier Liquor and Domestic Sewage		Rope and Rag Pulp Cook Liquor and Domestic Sewage	
	High-Rate Filter	Act. Sludge[1]	High-Rate Filter[2]	Act. Sludge[1]	High-Rate Filter	Act. Sludge[1]
B.O.D. loading (lb./1,000 cu. ft./day)	52.6	25.3	67.2	53.4	50.0	38.5
B.O.D. removal (%)	93.5	90	95.8	97.5	98.7	95.3
N used (lb./100 lb. B.O.D. rem.)	6.3	4.7	5.4	5.3	7.4	6.1
P used (lb./100 lb. B.O.D. rem.)	1.3	1.8	0.7	1.1	0.60	0.64
Ind. waste concentration (%)	22.0	20.0	10.0	10.0	1.0	1.0
Temperature (°C.)	27	30	29	30	28	30

[1] Sludge age corresponds to the loading noted and 1,500 p.p.m. aeration solids (nominal).
[2] Average of Runs II, III, and VII.

quirements are not in good agreement, except in the last case involving the use of rope and rag pulp liquor. In all cases the requirements of the filters were less than with activated sludge, just the opposite of the case of nitrogen. It is known that phosphates may be occluded in sludges and slimes under conditions where the pH is favorable. Since the pH of activated sludge effluents produced under laboratory conditions is usually in the range of 8 to 9 and trickling filter effluents in the range of 7 to 8, it is reasonable to assume that the trickling filter results are more accurate and that those obtained with activated sludge are apt to be high.

Industrial Waste Treatment with Limited Supplementation

In the treatment of industrial wastes deficient in nitrogen and phosphorus, the operator of the treatment facilities is interested in knowing whether he needs to add such nutrients to satisfy the maximum requirements or whether he can obtain as satisfactory results at some lower level and realize considerable savings in nutrient costs. Helmers *et al.* (5) have shown that satisfactory treatment can be obtained with activated sludge at nutrient levels considerably below those indicated as maximum requirements. Therefore, it seemed desirable to study the behavior of filters with limited nutrient supplies. Two rather extensive runs were made to obtain such information. Nitrogen requirements were studied using a cotton kiering waste having a deficiency of nitrogen, but a plentiful supply of phosphorus.

In the first of the runs made (Run VIII), filters B and C were fed with cotton kiering waste in as nearly identical a manner as possible. The feed to filter B was supplemented with 1.6 p.p.m. of nitrogen, whereas the feed to filter C was supplemented with 5.2 p.p.m. of nitrogen. From the data for this run (Tables IV and V) it will be noted that the B.O.D. loading was

TABLE IV.—Effects of Supplemental Nitrogen—Experimental Conditions and Process Efficiency (Run VIII)

Item	Filter	
	B	C
Raw cotton kiering waste in feed (%)	2.6	2.6
Settled sewage in feed (%)[1]	5	5
Supplemental N added (p.p.m.)	1.6	5.2
Volumetric loading data:		
Recirculation ratio	3:1	3:1
Feed application rate (g.p.d./sq.ft.)	115	115
Over-all application rate (g.p.d./sq.ft.)	460	460
B.O.D. data:		
Loading (lb./sq.ft./day)	0.33	0.33
Feed (p.p.m.)	347	339
Effluent (p.p.m.)	13	6
Removal (%)	94.5	98
Temperature (°C.)	25.2	25.2

[1] Balance made up with tap water.

TABLE V.—Effects of Supplemental Nitrogen—Analyses and Nutritional Relationships (Run VIII)

Item	Filter B	Filter C
Feed mixture anal.[1]:		
B.O.D. (p.p.m.)	347	339
Total N (p.p.m.)	14.6	16.9
Org. N (p.p.m.)	12.0	12.8
Total P (p.p.m.)	3.07	2.95
Effluent anal.:		
B.O.D. (p.p.m.)	13	6
Total N (p.p.m.)	6.9	7.5
Org. N (p.p.m.)	5.7	5.3
Total P (p.p.m.)	1.98	1.59
Nutritional relationships:		
Ratio B.O.D. removed/N utilized	44	35
Lb. N used per 100 lb. B.O.D. removed	2.3	2.9
Ratio B.O.D. removed/P utilized	305	240
Lb. P used per 100 lb. B.O.D. removed	0.33	0.42

[1] Including supplemental N.

rather low and, as a result, the effluent B.O.D. was very low in each case. However, it showed some deterioration with the more limited supply of nitrogen. These data indicate that good operation can be expected at such B.O.D. loadings with as little as 2.3 to 2.9 lb. of available nitrogen per 100 lb. of B.O.D. removed. These values are in good agreement with those reported by Helmers *et al.* (5) for activated sludge.

A second run was made using limited supplementation with nitrogen (Run IX) to study the behavior of the filters at higher B.O.D. loadings. The results (Tables VI and VII) may be compared

TABLE VI.—Effects of High Loading and Limited Nitrogen—Experimental Conditions and Process Efficiency (Run IX)

Item	Filter B	Filter C
Raw cotton kiering waste in feed (%)	4.46	3.33
Settled sewage in feed[1]	5.0	5.0
Supplemental N added (p.p.m.)	5.5	4.5
Volumetric loading data:		
Recirculation ratio	5:1	4:1
Feed application rate (g.p.d./sq.ft.)	115	115
Over-all application rate (g.p.d./sq.ft.)	690	575
B.O.D. data:		
Loading (lb./sq.ft./day)	0.69	0.52
Feed (p.p.m.)	718	537
Effluent (p.p.m.)	114	66
Removal (%)	84.3	87.8
Temperature (°C.)	26.4	26.4

[1] Balance made up with tap water.

TABLE VII.—Effects of Areal Loading—Analyses and Nutritional Relationships (Run IX)

Item	Filter B	Filter C
Feed mixture anal.[1]:		
B.O.D. (p.p.m.)	718	537
Total N (p.p.m.)	27.3	20.0
Org. N (p.p.m.)	22.4	17.1
Total P (p.p.m.)	5.45	4.03
Sol. P (p.p.m.)	4.16	3.26
Effluent anal.:		
B.O.D. (p.p.m.)	114	66
Total N (p.p.m.)	13.6	10.0
Org. N (p.p.m.)	12.3	9.3
Total P (p.p.m.)	3.66	2.97
Sol. P (p.p.m.)	3.02	2.19
Nutritional relationships:		
Ratio B.O.D. applied/total N applied	26	27
Ratio B.O.D. removed/N utilized	44	47
Lb. N removed per 100 lb. B.O.D. removed	2.3	2.1
Ratio B.O.D. applied/total P applied	131	133
Ratio B.O.D. removed/P utilized	337	445
Lb. P removed per 100 lb. B.O.D. removed	0.30	0.23

[1] Including supplemental N.

with the data for kiering liquor (Table III), where a nitrogen deficiency did not exist.

It may be seen from Table VI that the effluent B.O.D. removals were rather poor as compared to the results shown in Table III and, also, those obtained in the previous run. The data given in Table VII show that about the same amount of nitrogen was used per 100 lb. of B.O.D. removed in each filter and the results compare very favorably with the results for filter B in Table V.

These data serve to illustrate that the degree of nutritional deficiency which can be tolerated will depend upon B.O.D. loading to a large extent and the quality of effluent that must be produced.

Nutritional Aspects during Maturing of New Filters

It has been shown previously that a considerable saving of nitrogen may be accomplished on well-stabilized filters without sacrificing seriously the quality of the effluent produced. Since the development or maturing period of filters is a critical period in their life,

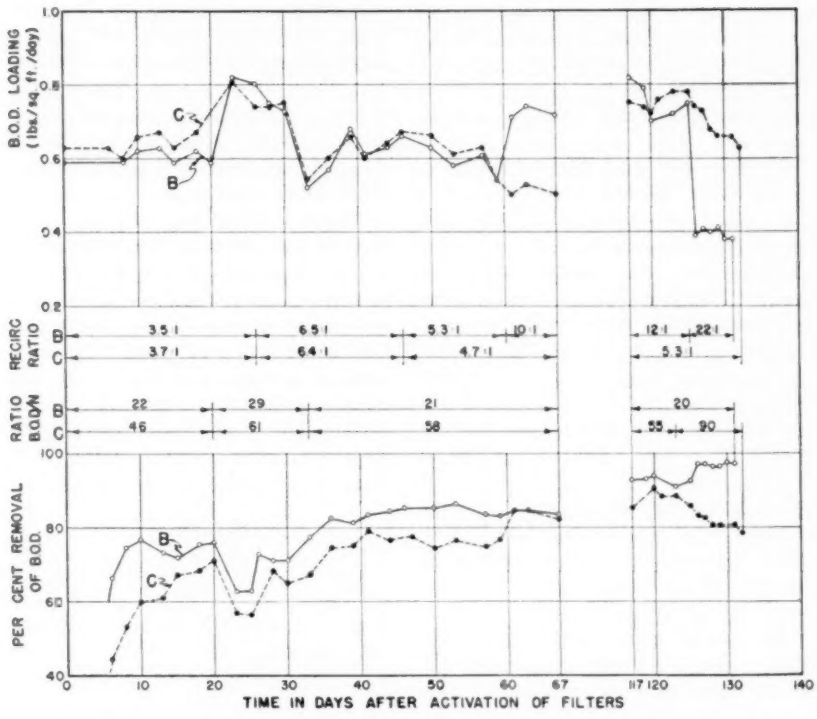

FIGURE 1.—Effect of nitrogen deficiency on the maturing and efficiency of high-rate filters.

it seemed important to evaluate the importance of nutritional balance.

The filter stones were removed from filters B and C and scrubbed to remove all adherent growths. After replacing the stones in the filters, filter B was fed with cotton kiering waste with nitrogen added to give a B.O.D. to nitrogen ratio of approximately 20 to 1. Filter C was fed kiering liquor without supplementation. Inasmuch as the kiering liquor contained excess phosphorus, the differences noted may be attributed to the difference in nitrogen content. This study was conducted over a period of 132 days. The results are shown in Figure 1, together with pertinent conditions of operation.

Although it was planned to hold the B.O.D. loading uniform at 0.6 lb. per square foot per day during the first 60 days, uncontrollable circumstances made it impossible. However, during this period the B.O.D. loadings to both filters were held essentially the same. Filter C, which received the unsupplemented waste, matured much more slowly, requiring about 20 days, whereas filter B developed to a fairly stable condition in less than 10 days. These data illustrate that rapid development of trickling filter slimes will be favored by supplying nitrogen in amounts corresponding to maximum requirements during the "breaking-in" period.

Both filters reflected the high B.O.D. loadings imposed on them following the 20th day by exhibiting a reduced B.O.D. removal. A reasonable measure of recovery, however, was achieved before the B.O.D. loading was reduced

to the desired level. Throughout the entire 60-day period filter C, receiving the unsupplemented feed mixture, gave quite inferior results, as would have been predicted from previous considerations.

On the 46th day, the recirculation ratios were decreased slightly, but little effect was noted. On the 59th day, the loading of filter B, receiving supplemented feed, was increased to about 0.7 lb. per square foot per day and the recirculation ratio was increased to 10 to 1. At the same time, the loading of filter C was decreased. While B.O.D. removal in filter B remained essentially unchanged, that in filter C increased markedly to almost the same value as that of filter B. At a B.O.D. loading of about 0.5 lb. per square foot per day and a ratio of B.O.D. removed to nitrogen utilized of about 58, filter C removed 84 per cent of the B.O.D. applied to it.

The period from the 67th to the 117th day was spent in performing certain investigations not pertinent to this paper. However, the B.O.D. to nitrogen ratios were continued as before throughout this period.

On the 115th day, high loadings were imposed on both filters and the effects observed for 10 days. The recirculation ratio for filter B was increased to 12 to 1 and that for filter C to about 5.3 to 1. Despite a decided nitrogen deficiency, filter C was by this time about 88 per cent and filter B about 93 per cent efficient. It is significant to compare these results with those obtained on the 30th day.

In concluding this run, it was proposed to operate filter B at a decreased B.O.D. loading and a very high recirculation ratio, and to operate filter C at a B.O.D. loading of about 0.7 lb. per square foot per day at a recirculation ratio of 5 to 1, maintaining a B.O.D. to nitrogen ratio of 90 by supplementing the kiering waste with dextrin.

The effects were notable. The efficiency of filter B rose to 97 per cent, reducing the B.O.D. of the feed from 600 p.p.m. to 20 p.p.m. The efficiency of filter C fell considerably during a 10-day period and would, undoubtedly, have continued to fall had the experiment been continued.

The results of this run are considered of real significance to the engineer who is to recommend a biological treatment process for treatment of nutrient-deficient wastes. They demonstrate that the well-known flexibility and resistance to shock loadings of the high-rate trickling filter may be extended to include the ability to operate efficiently for short periods under conditions of extreme nutrient deficiencies.

Summary

Laboratory-scale experiments were conducted on the stabilization of industrial wastes by the two-stage high-rate trickling filter. The industrial wastes studied were a bleachery waste, a cotton kiering waste, a rag-rope pulp cook waste, and a rope pulp cook waste. All wastes were treated in conjunction with domestic sewage. In addition, the cotton kiering waste was treated without admixture with domestic sewage.

The nitrogen and phosphorus requirements of the waste and waste-sewage mixtures were calculated and compared with comparable data gathered on the activated sludge process. Effects of nitrogen deficiencies were examined with relation to filter efficiency, and relationships between nitrogen and phosphorus utilization investigated.

The effect of a marked nitrogen deficiency on the seeding of a high-rate trickling filter was also investigated.

Conclusions

1. Bleachery waste, cotton kiering liquor, rope and rag pulp cook liquor,

and rope pulp cook liquor can be successfully treated in admixture with domestic sewage on high-rate two-stage trickling filters.

2. In the presence of excess nitrogen and phosphorus, the nitrogen requirements of such waste-sewage mixtures varied from 4.7 to 7.4 lb. per 100 lb. of B.O.D. removed. The phosphorus requirements varied from 0.36 to 1.25 lb. per 100 lb. of B.O.D. removed.

3. In general, the results of studies of nitrogen and phosphorus utilization in fill-and-draw type activated sludge pilot plants may be translated to high-rate trickling filter pilot-plant operation provided the ages of the sludges utilized correspond to those that would attain under conditions of a B.O.D. loading of 25 to 70 lb. per 1,000 cu. ft. per day, and 1,500 p.p.m. aeration solids.

4. Cotton kiering liquor of the type studied can be successfully treated in conjunction with as little as 5 per cent sanitary sewage by the high-rate two-stage trickling filter with B.O.D. loadings as high as 60 lb. per 1,000 cu. ft. and at over-all rates of application as high as 100 m.g.a.d.

5. A nitrogen deficiency results in little impairment of the operating characteristics of the high-rate trickling filter, up to B.O.D. to nitrogen ratios of 40. Above ratios of B.O.D. to nitrogen of 40, impairment of efficiency increases.

6. Maturing of filters is retarded by a nitrogen deficiency in the substrate.

7. Phosphorus utilization by the high-rate trickling filter is governed primarily by the nature of the substrate, and to some extent by the amount of nitrogen available.

Acknowledgment

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POLLUTION ABATEMENT NEEDS OUTLINED FOR PITTSBURGH–HUNTINGTON STRETCH OF OHIO RIVER

In a recent 36-page report entitled "Ohio River Pollution Abatement Needs —Pittsburgh-Huntington Stretch," the Ohio River Valley Water Sanitation Commission presents its findings and recommendations on treatment requirements for maintaining oxygen and bacterial quality objectives in that section of the river. The investigation reported on was made for the purpose of evaluating pollution conditions resulting from sewage discharged into the upper stretch of the Ohio River and determining necessary remedial measures in terms of sewage treatment requirements. The report is the third of a series.

Recommendations of the report, as regards treatment of all sewage discharged into the Ohio River between Pittsburgh, Pa., and and Huntington, W. Va., are as follows:

1. Substantially complete removal of settleable solids.

2. Removal of not less than 45 per cent of the total suspended solids.

3. Treatment of sewage discharged in Pennsylvania above the Allegheny-Beaver county line in accordance with requirements of the Pennsylvania Sanitary Water Board (namely, approximately 50 per cent reduction in B.O.D.).

4. Reduction in coliform organisms of not less than 80 per cent during the months of May through October and not less than 85 per cent during the months of November through April.

The recommendations as set forth are based on water quality standards that will assure a dissolved oxygen content suitable for normal aquatic life, natural purification processes, and other legitimate uses, as well as a bacterial quality suitable for water supplies and recreational uses, including bathing.

Stream Pollution

BACTERIOLOGICAL STUDY OF IRRIGATED VEGETABLES

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A recent sanitary survey (1) of the South Platte River Basin indicated that several streams used for crop irrigation were heavily polluted. It has also been found that irrigation waters from streams in other areas of the United States contained similar sewage pollution. The use of polluted waters to irrigate vegetables that are eaten uncooked has generally been considered hazardous by public health officials.

Rudolfs, Falk, and Ragotzkie (2) have reviewed the literature relative to the presence and persistence of enteric bacteria in soil, sewage, sludges, and water, and on vegetation. It appeared that vegetables grown in polluted soils could become contaminated with disease-producing organisms that might survive for periods of time varying from a few days to several weeks. Rudolfs *et al.* (3) and Falk (4) found that, except for tomatoes with abnormal stem ends, there was no material difference in the coliform counts per gram of tomatoes grown on three plots of land; one plot irrigated with settled sewage concurrently with growth, one plot irrigated before planting only, and one unirrigated. They were able to recover *Salmonella cerro* and *Salmonella alkalescens* for two to seven days after the organisms were sprayed on the growing tomatoes. Mallmann and Litsky (5) studied the survival of selected enteric organisms in various types of soil and concluded that coliform organisms were found to persist in soil for long periods of time; enterococci were found to die out rapidly; and that virulent typhoid bacilli died out much more rapidly than did the enterococci. Dunlop, Twedt, and Wang (6) (7) recovered *Salmonella* organisms from a significant number of irrigation water samples contaminated with effluent from a primary sewage treatment plant. The same organisms were recovered once from vegetables (celery) irrigated with this water. Gaub (8) reported the isolation of *Shigella paradysenteriae* (Flexner) from cabbage grown on farms north of Denver, Col., irrigated with sewage-contaminated water. Because the cabbage had been subjected to the usual processes of harvesting and marketing the source of contamination was not determined.

Wright (9) has summarized the economic importance of irrigation on the agricultural development of this country. The relationship of the use of sewage-polluted water for irrigating vegetables to the occurrence of enteric disease has not been established. Further laboratory and epidemiological evidence regarding this relationship is urgently needed.

This study, covering a period of three growing seasons, was initiated in 1949 to provide additional data relative to the presence of pathogenic enteric organisms and the coliform and

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enterococcus densities on vegetables irrigated with sewage-polluted water.

Materials and Methods

Collection of Samples

Samples were collected from farms using water free of known pollution, as well as from farms using water heavily polluted with sewage. Samples of plants to be examined, soil at the base of plants, and water from the irrigation ditch were usually collected at the same time. Plant samples were taken by placing a sterile 60-lb. paper bag over the plant and pulling it out of the ground (celery) or by cutting the stem with a sterile knife (cabbage). The top of the bag was folded several times to prevent entrance of contamination. Soil samples were collected in 1-qt. sterile glass jars, using a sterile spoon. Water samples were collected by dipping a sterile 2-gal. jar into the water of the irrigation ditch.

Preparation of Samples

The soil samples and most of the plant samples were prepared for bacteriological examination by "rinse" procedures. A 200-g. portion of sample was placed in a sterile, 8-l., widemouthed jar; 2 l. of sterile phosphate-buffered distilled water (10) were added; and the contents were shaken 50 times through 1-ft. vertical excursions. Some of the plants were minced in buffered distilled water for 2 to 5 min. in a high-speed electric mixer (blender).

Bacteriological Methods

Coliform organisms were enumerated by the M.P.N. procedure, confirmed test, as described in "Standard Methods" (10). Enterococcus determinations were made by the method of Winter and Sandholzer (11). Results were expressed in M.P.N. per 100 ml. of water or 100 g. of soil or plant.

Because of the small number of pathogenic enteric organisms present in the materials under study, the bacteria from 1- or 2-l. samples were concentrated by centrifugation or flocculation and examined by the following procedures: incubation at 37° C. for 24 hr. in Kauffmann's tetrathionate broth as modified by Galton and Hardy (12); streaking on brilliant-green, S.S., and bismuth sulfite agar plates, and incubation for 18, 18, and 46 hr., respectively; transfer of representative colonies to urea agar; retransfer of urease-negative cultures to triple sugar iron agar; testing of possible *Salmonella* and *Shigella* organisms for indol production, citrate utilization, and production of acetyl methyl carbinol. Final identification included the usual biochemical tests and agglutinations with polyvalent and group antiserums. All cultures that showed biochemical and serological reaction of *Salmonella* were identified as to species by the USPHS Communicable Disease Center, Chamblee, Ga.

Results

Data relative to the occurrence of enteric bacteria in the South Platte River above and below the Denver outfall sewer, in irrigation water, in soil, and on vegetables, are summarized in Table I. Results showing the occurrence of coliform organisms in unpolluted water, and soil and vegetables irrigated with it, are summarized in Table II.

It is shown that the coliform densities of South Platte River and irrigation waters derived therefrom are high, having mean M.P.N. values of 430,000 and 230,000, respectively. That the coliform indices of soils and vegetables reflect the coliform content of the waters with which they are irrigated, is evident from inspection of Tables I and II. The median coliform M.P.N. for soils irrigated with polluted water is 260,000, and only 7,600 when irrigated with unpolluted water. For vegetables the comparable indices are 20,000 and 930. Except for the quality of water, all known environmental fac-

TABLE I.—Enteric Bacteria in South Platte River, Irrigation Water, and Soil, and on Vegetables

Source	No. of Samples	M.P.N.[1]						*Salmonella*	
		Coliform			Enterococcus			No. of Samples	
		Median	Maximum	Minimum	Median	Maximum	Minimum	Examined	Positive
South Platte River:									
Above outfall	4	4,900	9,300	2,300	26	43	9.1	0	—
Below outfall	11	430,000	2,300,000	1,500	2,300	93,000	14	4	4
Irrigation water	68	230,000	43,000,000	9,300	2,300	39,000	14	16	11
Soil	102	260,000	300,000,000	170	<38	240,000	<30	7	1
Vegetables	46	20,000	46,000,000	<30	<30	9,300	<30	10	0

[1] M.P.N. per 100 ml. of water or per 100 g. of plant or soil.

tors, such as fertilization, cultivation, climatic conditions, etc., are similar. It is apparent that the coliform index of the vegetables is much lower than for the soil on which they are grown.

Other data indicate that the coliform M.P.N.'s of leafy vegetables (lettuce, celery, and cabbage) tend to be greater than the M.P.N.'s of smooth vegetables (tomatoes and peppers). For 39 samples of leafy vegetables the median coliform M.P.N. was 39,000 per 100 g. For 8 samples of smooth vegetables the median M.P.N. was 1,000. The median coliform M.P.N. of the irrigation waters for both groups was 230,000.

In the polluted irrigation waters studied, the median enterococcus content per 100 ml. (Table I) was 2,300, with a maximum of 39,000 and minimum of 14. High enterococcus content tends to accompany high coliform count. For soil and vegetable samples the results of enterococcus examination were erratic, showing no relationship to the coliform M.P.N. The median enterococcus M.P.N. for 102 soil samples was less than 38 per 100 g., and for 46 vegetable samples less than 30.

It is shown in Table I that *Salmonella* were recovered from each of 4 South Platte River water samples, and from 11 of 16 polluted irrigation waters. *Salmonella* were isolated from only 1 of 7 soil samples examined and were not found in the washing of 10 vegetables. *Salmonella* were also recovered from 4 of 6 sewage samples.

From the 20 samples known to have contained *Salmonella*, 222 colonies were identified as such. The identified strains comprised 16 types. Nine types found in irrigation water were also present in sewage, or in river water, or in both. Two types were found in sewage only, 3 types in river water only, and 2 in irrigation water only.

Seven different types of *Salmonella* were isolated from one sample of raw sewage, and 6 types from a sample of treated sewage. The examination of one irrigation water sample yielded 8 different types. The types of *Salmonella* recovered, in order of descending occurrence, were as follows:

Type	Occurrence	No. of Colonies
S. montivideo	14	87
S. typhimurium	11	46
S. newport	7	13
S. oranienburg	5	12
S. derby	5	8
S. bareilly	4	17
S. bredeney	3	9
S. panama	3	5
S. give	2	4
S. anatum	2	2
S. enteritidis	2	2
S. muenschen	1	7
S. kentucky	1	7
S. paratyphi B	1	1
S. newington	1	1
S. canoga	1	1

Discussion

The pollution content of the irrigation water is reflected in the trend for

TABLE II.—Coliform Densities of Soil and Vegetables Irrigated with Unpolluted Water

Sample	No. of Samples	M.P.N.[1]		
		Median	Maximum	Minimum
Water	5	<3.0	9.1	<3.0
Soil	4	7,600	17,000	2,800
Vegetables	3	930	1,200	91

[1] M.P.N. per 100 ml. of water or 100 g. of plant or soil.

high enterococcus content to accompany high coliform content. In soils, direct relationship of enterococcus M.P.N. to coliform M.P.N. is not apparent. Mallmann and Litsky (5) have reported that coliform organisms persist in soils for long periods of time, while enterococci die out rapidly, and that typhoid bacilli survive for a shorter period than enterococci. The period of time between the last application of irrigation water and collection of soil samples may be responsible for the erratic enterococcus results and low *Salmonella* content in the soils examined in this study.

Coliform and enterococcus M.P.N.'s were also determined for 12 of the 16 irrigation water samples from which *Salmonella* were isolated (Table III). The data presented show no significant differences in the coliform and enterococcus indices of samples from which *Salmonella* were recovered and of samples in which *Salmonella* were not found.

Dunlop *et al.* (7) isolated *Salmonella* from 8 of 11 irrigation water samples examined, but recovered *Salmonella* from only 1 of 14 vegetable samples. The calculated M.P.N. value for this one sample was 1.32 *Salmonella* per 100 g. of vegetable. In this study 11 of 16 irrigation water samples showed the presence of *Salmonella* organisms. No organisms of this group were found in 10 vegetable samples. These findings indicate that the *Salmonella* content was quite low for vegetables when irrigated with sewage-polluted waters.

McCollough and Eisele (13), in a study of experimental human salmonellosis, reported that *S. anatum* strain I produced illness in human volunteers in dosages of from 587,000 to 860,000 organisms. For strain II, 44,500,000 to 67,200,000 organisms were required. The variations in the number of organisms required to produce disease by the strains studied indicate that the dosage of other strains and types might vary over wide ranges. The dosages for some enteric bacteria have been presumed to be of considerably smaller magnitude. The infectious human dosage for the other types of *Salmonella* isolated from vegetables is not known. Because the infectious dose of many en-

TABLE III.—Coliform M.P.N., Enterococcus M.P.N., and *Salmonella* Content of Irrigation Water

Sample	M.P.N. per 100 ml.		*Salmonella* (No. types)
	Coliform	Enterococcus	
Brantner ditch, 5|7|51	230,000	2,300	0
Brantner ditch, 5|14|51	230,000	230	4
Brantner ditch, 6|4|51	23,000	430	2
Gardner's ditch, 6|4|51	15,000	230	2
Gardner's ditch, 6|20|51	93,000	930	0
Gardner's ditch, 6|26|51	1,500,000	4,300	4
Rocky Mt. ditch from Clear Creek, 9|12|49	23,000,000	4,300	2
Clear Creek, Copeland Lake, 8|1|51	93,000	430	0
Clear Creek, Copeland Lake, 8|6|51	9,300	39	0
Mixed Brantner ditch and Clear Creek, 6|4|51	23,000	230	1
Lower canal, 5|7|51	43,000	2,300	2
Lower canal, 6|4|51	43,000	430	0

teric pathogens is unknown, the health hazard of eating vegetables irrigated with polluted water cannot be completely evaluated at this time. However, the presence of polluted water in the proximity of the vegetables introduces the possibility of contamination during harvesting and preparation for market.

Summary

1. The coliform content of irrigated soils studied reflects, in general, the coliform density of the water they receive.

2. Vegetables irrigated with waters of high coliform count exhibit a higher coliform flora than vegetables irrigated with relatively pure water.

3. The coliform density of leafy vegetables irrigated with polluted water is higher than smooth vegetables grown under similar conditions.

4. Under the condition of this study, the enterococcus indices of soils and vegetables showed no direct relationship to the indices of irrigational waters.

5. *Salmonella* were present in the irrigation waters in readily demonstrable numbers, were present in soils in only low concentration, and were insufficiently numerous on the vegetables to be demonstrated by the procedures used.

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THE OPERATOR'S CORNER

CONDUCTED BY HERBERT P. ORLAND

INITIAL DIGESTION PROBLEMS IN A NEW PLANT*

BY ANTON E. SPARR

Superintendent, Bay Park Sewage Treatment Plant, Nassau County, N. Y.

A most unusual problem was faced on opening day at the Nassau County Bay Park sewage treatment plant. Both of the primary digesters were filled with a cold sludge and the sludge heating system was not functioning. The solution to this difficulty took time.

Sludge Handling Facilities

The sludge digestion system consists of two primary and two secondary digesters. Each unit is 90 ft. in diameter with about 31-ft. side-wall depth; each is equipped with a floating cover. There are four separate points for the introduction of the sludge. One is at the center of the tank and above the maximum liquid level; the other three are equally distributed at a level about one third from the top and in the sludge liquor zone.

Two external sludge heaters are used to heat the sludge. Variable-speed centrifugal pumps, used to circulate the sludge between the digesters and the heaters, are also used to transfer the digested sludge to the secondary digesters, which are called "separators." Engine jacket water circulating through the heaters is the primary source of heat for sludge heating. This heat is supplemented by the use of converters, which transfer steam heat to the jacket water after it leaves the engines.

Slow Temperature Rise

For about a year prior to the introduction of sewage, the plant had been receiving cesspool collections, which were pumped to both digesters. These collections contained large quantities of sand and gravel, which filled the digester cones and clogged the sludge lines. Persistent backflushing and pumping eliminated this problem.

On opening day, December 4, 1951, both digesters were filled with a 50° F. sludge, which was difficult to heat. The high heat demand of the low-temperature sludge lowered the return jacket-water temperature below the critical value, materially affecting engine operation. This precluded the use of the engine jacket water without supplementary heat from the converters. It wasn't until January 28, 1952, that the contractor was successful in correcting the several defects in the converters and their regulating equipment. Each digester now had a heat requirement backlog of 500,000,000 B.t.u., exclusive of radiation losses. To make the problem more acute, about 8 tons of dry solids, along with scum, were added each day. Room was made in the digesters by transferring the sludge to the separators for temporary

* Presented at 1953 Annual Meeting, New York Sewage and Industrial Wastes Assn.; New York, N. Y.; Jan. 22–23, 1953.

storage until satisfactory digestion conditions were attained.

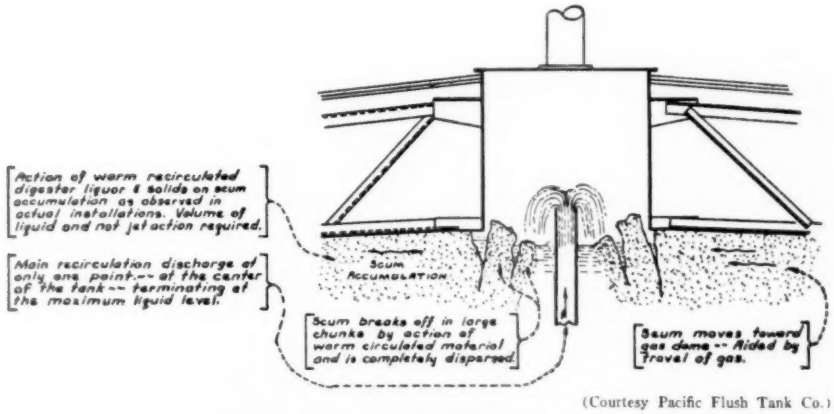
When the heating problem was solved it was found expedient to apply heat to one digester without sludge additions. All of the raw sludge was sent to the second digester and transfers were made from this unit to the separators. It took 15 days before the digester temperature reached 90° F. The lessened heat demand of the first digester permitted the application of a limited amount of heat to the second. For the next 17 days one-third of each day's raw sludge was pumped to the first digester; thereafter the daily raw sludge pumpage was handled by this unit along with an interchange of sludges between the two digesters. Heating and the warm seeding sludges from the first digester helped to speed up the start of active digestion in the second.

Scum Blanket

During the period of raw sludge additions to the cold digester, a 5-ft. blanket of scum had formed in this unit. This blanket persisted until a change in sludge introduction was made. At the start, all four sludge feeding point valves were open. Because of the above-the-liquid elevation of the center feeding point, practically all of the raw sludge was introduced through the other three. The valves for these three were closed and all of the raw and the heated circulating sludges were then introduced at the center of the tank above the scum blanket. This mixture of sludges beat a hole through the scum blanket (Figure 1), permitting the warm sludge liquor to act upon the blanket submerged by the floating cover.

Foaming started when the scum began to digest, and lasted for three days, requiring the cleaning of the digester walls and cover. Since that time the scum has digested well with no blanket formation.

The author is in complete agreement with those who maintain that scum should be kept out of the digestion system—but for an entirely different reason. This is due to a sad experience with scum in that it formed an irregular lining in the raw sludge line to the digester. This lining averaged about 1¼ in. in thickness in a 6-in. line. It is believed that the scum combined chemically with some material in the sludge to form a hard, highly adhesive lining. Various solvents and heat were tried; petroleum ether appeared to be the most effective, but was not practical. A power-driven sewer cleaning


Action of warm recirculated digester liquor & solids on scum accumulation as observed in actual installations. Volume of liquid and not jet action required.
Main recirculation discharge at only one point -- at the center of the tank -- terminating at the maximum liquid level.
Scum Accumulation
Scum breaks off in large chunks by action of warm circulated material and is completely dispersed.
Scum moves toward gas dome -- Aided by travel of gas.

(Courtesy Pacific Flush Tank Co.)

FIGURE 1.—Action of digester liquor recirculation on scum accumulation.

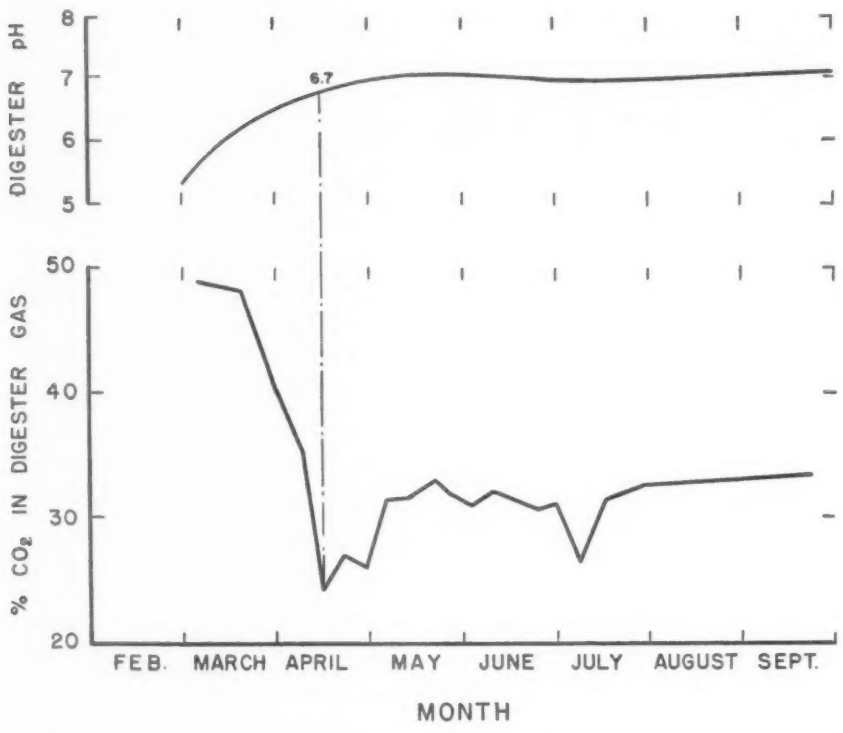


FIGURE 2.—Variations in sludge pH and carbon dioxide content of gas in the second digester.

auger was used to scrape off this material.

Solids Build-Up

With the primary digesters under control, the stored solids in the separators were then gradually returned to the digesters. These solids digested surprisingly well. The further delay necessitated by the digestion of these solids resulted in a large solids build-up in the digestion system. The use of emergency sand beds, vacuum filters, and sludge lagoons reduced these solids to a satisfactory level.

Figure 2 shows the variations of both the sludge pH and the carbon dioxide content of the digester gas as digestion progressed in the second digester. The pH curve is typical, starting with a pH of 5.3 and building up to and levelling at about 7.2. It was anticipated that a poor quality, unburnable gas would be produced when gasification started, therefore it was wasted to the atmosphere through the gas dome inspection openings. Weekly accurate gas analyses were not made until the carbon dioxide content decreased to about 50 per cent. The lower curve indicates a falling off of the carbon dioxide content to a minimum of 24.1 per cent at a pH of 6.7; after that it increased to about 33 per cent and has remained substantially at that level since.

LIMING A DIGESTER

By B. F. Rockecharlie

Superintendent, Sewage Treatment Plant, Portsmouth, Va.

Much has been written pro and con concerning the use of lime in digesters. It seems that those who frown upon this practice are becoming increasingly vehement, but since it has been used at Portsmouth, Va., on several occasions to cure an ailing digester, it is believed that it can be of great help to others with similar operational setups.

Plant Facilities

The Portsmouth plant is a primary treatment plant with two-stage digestion and an external heat exchanger. The primary digester has three drawoff pipes at the bottom: one in the center, and one at each side. There are also three sludge inlet pipes: one at each side about half-way up the tank, and one at the top center. The other regularly used pipe is the automatic overflow, which leads to the secondary digester.

The primary tank contents are kept homogeneous by continually withdrawing sludge through one of the bottom pipes, passing it through the external heat exchanger, and back through one of the inlets. If no heat is needed, the hot water is diverted from the exchanger, but circulation is continued. The drawoff point is changed every 8 hr., the inlet point being changed every hour.

Ordinarily, 10 min. pumping per hour of raw sludge (800 gal. at 5 per cent solids) is sufficient to keep the sludge drawn down in the sedimentation basins. Raw sludge is mixed with circulating sludge at a tee in the pipe gallery; no other heat is applied to the raw sludge. The temperature of the

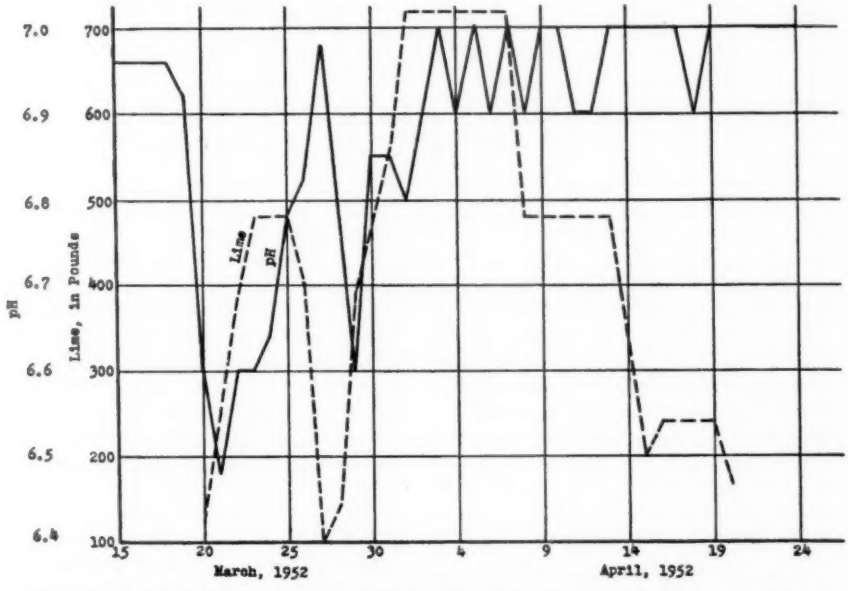


FIGURE 1.—Effect of lime addition to raw sludge on digester pH, Portsmouth, Va.

primary digester is maintained at 95° F. and the solids at about 5 per cent.

Liming

There are, of course, many things that can cause the pH of a healthy digester to start falling. Experience has taught that it is wise to begin liming before beginning to look for the trouble. It is not believed that moderate liming can harm a digester. Realizing that the word "moderate" is much too general, the following is presented as an indication of the manner in which the lime was introduced into the Portsmouth digesters during the period covered by Figure 1.

From Rudolf's lime chart (1) it was determined that about 20 lb. of hydrated lime per 800 gal. would be needed to bring the raw sludge (pH 5.8) to pH 7.3. On the hour, therefore, the lime was mixed in about 100 gal. of water in the scum pit and the solution was pumped to the digester. This was followed immediately by the regular 10-min. pumping of raw sludge, through the same inlet pipe. The next hour the same procedure was followed, using a different digester inlet pipe. Circulation of the digester contents was continued as in normal operation.

Figure 1 shows that liming started with one-half the calculated amount per hour, and worked up to one and one-half times that amount, with at least 24 hr. at one rate of dosage. Lime dosages other than 240, 480, and 720 lb. resulted from changing the dosage rate during the day instead of at midnight.

Conclusions

Many of the ailments that cause a falling pH cannot be cured with lime, but quite often these intangibles are difficult to pin down. It is suggested that at such times the liming program be initiated before proceeding with the diagnosis. The lime, if used moderately, can do no harm to the digester, and it may save one from the embarrassment of a driveway covered with foam.

Reference

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INTERNAL SLUDGE MIXER OPERATION AT STAMFORD, CONN.*

By A. L. Wilcox

Sales Engineer, The Dorr Company, Stamford, Conn.

The problem of sludge digestion has been discussed at considerable length. This presentation is a summary of results obtained with a mechanical stirring device called a "draft tube mixer" installed in a digester. The reasons for mixing are (a) to control scum, (b) to aid in uniform heat distribution, and (c) to mix raw sludge intimately with well-digested seed sludge.

The design of the mixer for use in a fixed cover digester is shown in Figure 1. The number of mixers required for a given digester installation varies usually from 1 to 3, depending on the size of the digester and the capacity and size of the mixer selected. Each mixer consists of a high-speed, weedless type, cast-iron propeller operating in a steel draft tube supported on a concrete pier or by other suitable means. The propeller shaft is normally driven by a static-resisting V-belt drive from a motor with a sheet metal guard. The motor is mounted on an adjustable base

* Presented at 1953 Annual Meeting, New York Sewage and Industrial Wastes Assn.; New York, N. Y.; Jan. 22–23, 1953.

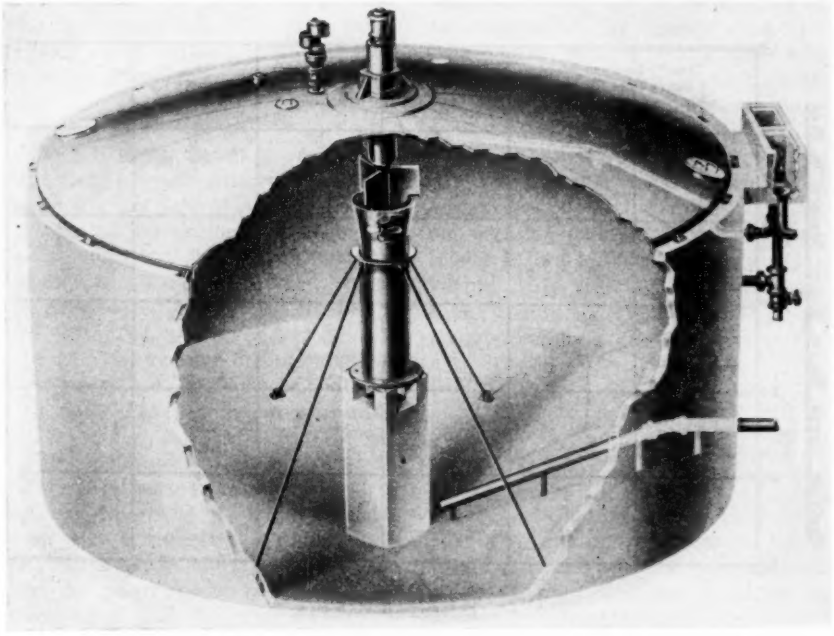

FIGURE 1.—Typical draft tube mixer for use in fixed cover digester.

plate. By means of suitable electrical controls the rotation of the propeller can be reversed so that the flow direction in the draft tube can be upwards or downwards.

Test of Unit

To determine the results with this unit, tests were conducted at the Stamford, Conn., sewage treatment plant, where a draft tube mixer was installed in one of two primary digesters, each of which is 50 ft. in diameter by 25 ft. sidewater depth and is operated in series with a gasholder-type secondary digester.

The load of raw sludge was divided as equally as possible between the two primary digesters for several weeks prior to sampling of the units. Then samples of sludge were taken at various levels in the digesters and tested for solids and volatile solids contents. The samples were collected by means of a depth bomb sampler dropped through the sample tube opening on the roof of the digester. On a 50-ft. diameter tank this sample tube is located about 15 ft. from the center.

Dry solids determinations at various levels in the digesters are plotted in Figure 2. Tank No. 1, equipped with a draft tube mixer, has uniform consistency for about the top half of the digester, which is that portion above the level of the bottom discharge ports in the draft tube, which are located at the 17.5-ft. level. Thickening in the bottom half of the digester is apparent from the data.

Tank No. 2, which is not equipped with a draft tube mixer, has considerable variation in dry solids content in the upper portion of the tank. The scum layer, about 5 ft. thick, contained 30.8 per cent dry solids on top.

Figure 3 shows the variation in volatile matter content in the sludge for both the mixed and unmixed tanks. In all cases the reduction in volatile sol-

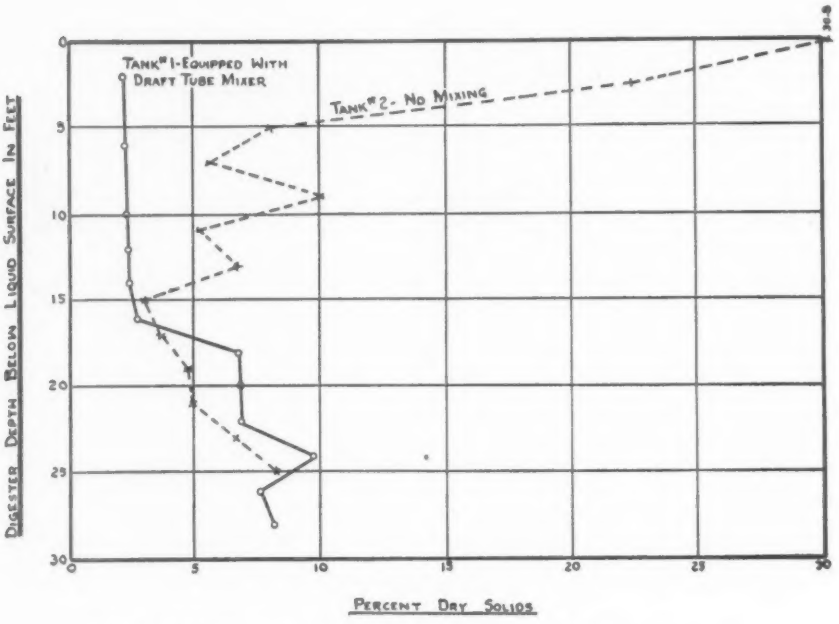

FIGURE 2.—Effect of mixing on dry solids content of digester contents.

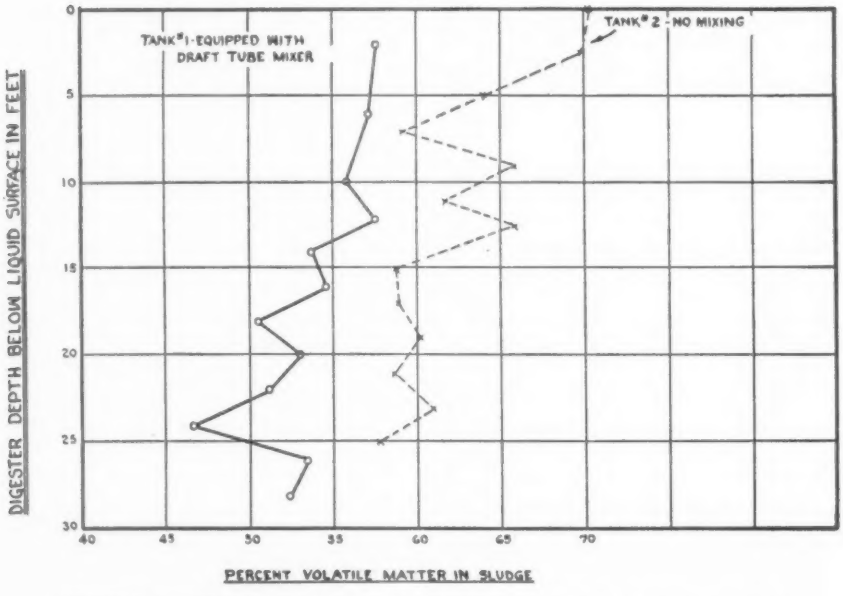

FIGURE 3.—Effect of mixing on volatile matter content of digester contents.

ids was greater in the mixed digester than in the unmixed. The scum layer in Tank No. 1 was of a very high volatile solids composition.

Plant Description

The Stamford, Conn., sewage treatment plant provides primary treatment for an average flow of 5.6 m.g.d. from a connected population of 45,000. Digester capacity of 3.3 cu. ft. per capita is provided. Pumpage of raw sludge averages 16,000 g.p.d. at 4 to 5 per cent solids, of which 76 per cent is volatile. The average detention in the digestion system is 29 days at 90° F., with daily gas production averaging 65,000 cu. ft.

The benefits of mixing are shown in the data presented. Scum control is perhaps the most apparent benefit, along with a reduction in volatile solids content of the digested sludge, and a resulting increase in gas production.

Mixing of digester contents may be accomplished by either an internal or an external sludge recirculation system. Intense mixing is obtainable with the internal mixer, thereby giving positive scum submergence and tank turnover. An additional advantage of the draft tube mixer is the low operating cost, because effective mixing and scum control are accomplished by 1 or 2 hr. of operation per day. Assuming electricity at 2¢ per kilowatt-hour, the following daily costs of operation have been computed from actual power measurements on digester mixers:

Digester Diameter (ft.)	Daily Cost ($)
20	0.05 to 0.10
50	0.20 to 0.40
75	0.80 to 1.60

In conclusion, it should be emphasized that mixing is important, but it is only one phase of a well-designed and well-operated digestion system in sewage treatment.

INTERESTING EXTRACTS FROM OPERATION REPORTS

1st Annual Operation Report for the Washington, Ind., Sewage Treatment Plant for the Year 1952

By Jesse A. Behle, *Superintendent*

In operation just a year, the Washington, Ind., sewage treatment plant provides comminution with stand-by hand-cleaned bar screen; flow measurement by Parshall flume; automatic pumping with wet well provision for addition of lime, alum, and chlorine; grit and grease removal by pre-aeration; primary settling; high-rate trickling filtration; final clarification; chlorination; and separate sludge digestion. The plant is designed for an average flow of 1.7 m.g.d. from a population of 17,000. The connected population is currently 11,000.

Equipment units are designed on the following bases: comminutor, 3.4 m.g.d.; raw sewage pumps, two at 1,750 g.p.m.; grease and grit chamber, 19.2-min. detention at design flow; air compressor, 75 c.f.m. at 5 p.s.i.; primary tank, 2.13-hr. detention at design flow; two trickling filters, 6-ft. depth and total area of 0.229 acre; final tank, 2.3-hr. detention at design flow; chlorine contact tank, 14-min. detention; two sludge digesters, each of 41,200-cu. ft. capacity; and five open sludge drying beds, each 50 ft. by 100 ft.

Table I summarizes operation data for the year.

TABLE I.—Summary of 1952 Operation Data for the Washington, Ind., Sewage Treatment Plant

Item	Average	Item	Average
Connected population (est.)	11,000	Final effluent (p.p.m.)	21
Sewage flow (m.g.d.):		Reduction (%)	84
Design	1.7	Suspended solids:	
Actual	0.94	Raw sewage (p.p.m.)	114
Grit removed (cu. ft./m.g.)	4.23	Primary effluent (p.p.m.)	29
pH:		Reduction (%)	75
Raw sewage	7.6	Final effluent (p.p.m.)	16
Final effluent	7.6	Reduction (%)	86
Digester supernatant	6.9	Sludge gas (cu. ft.):	
B.O.D.:		Per day	4,820
Raw sewage (p.p.m.)	129	Per capita per day	0.44
Primary effluent (p.p.m.)	36	Operating cost ($):	
Reduction (%)	72	Total	25,932.89
		Per m.g.	84.83

OPERATION NOTES FROM FORT WAYNE

By Paul L. Brunner

Superintendent, Sewage Treatment Works, Fort Wayne, Ind.

Sewage Service Rate Surcharges

Fringe areas and annexation problems are rapidly becoming a major headache for most cities and Fort Wayne is no exception. In areas operating under a sanitary district, sewer expansions and charges for suburban areas are covered and the rates are equitable. Fort Wayne's utilities, however, are operated by a Board of Public Works, whose jurisdiction stops at the city limits except for certain instances covered by special ordinances. It is under these special ordinances that sewers and sewage treatment facilities have been provided for suburban areas, which enjoy city facilities without paying city taxes. In a recent water expansion program, the water rate minimum was raised from $1.00 to $1.40 and an additional surcharge of 35 per cent was made on users outside the city limits. A similar surcharge was planned for sewage service rates, but the scarcity of published reports on the subject made it difficult to obtain information on what other typical cities charge. A surcharge of 100 per cent was agreed upon, and the ordinance was passed in July, 1952, without serious objections.

Safety

The plant safety record was still intact at the beginning of 1953, having gone 650 consecutive days without a lost-time accident. The middle of March will mark the end of two years, which should rate some sort of celebration. The plant is in the 70,000-man-hours per year bracket.

The Fort Wayne city utilities began another extensive safety program in January, 1953. Using two employees who are qualified instructors, first aid classes have been set up so that all utility employees will get the standard 10-lesson Red Cross course in first aid. Through the cooperation of the management, the classes are held on company time and the attendance and interest of the employees have been very gratifying. All those interested in safety appreciate the management's attitude toward such a program.

Nylon Flags

Experience with Nylon flags for the plant's 60-ft. flagpole may be of in-

terest. The data show that a Nylon flag lasts between two and three times as long as a cotton flag, but it also costs about as much more. Economically it's about a draw, but the Nylon flag makes a nicer appearance, which is hard to measure in dollars and cents. A 5/8-in. sash cord had been used for flag rope and when a rope broke, which was usually in inclement weather, the Fire Department and its 100-ft. aerial ladder truck had to be invited to come out to replace it. The last time this happened it was replaced with a 1/4-in. Nylon rope, which it is hoped will last at least in proportion to the cost.

Pump Station and Regulator Control

The Fort Wayne sewage utility is composed of two departments—maintenance and treatment. Heretofore, the maintenance or Sewer Department was responsible for the repair, cleaning, and upkeep of the sewers, catchbains, etc., as well as the operation and maintenance of the "spillover" regulators, two large lift stations, and several smaller lift stations. However, during heavy rain periods and high river flows, due to faulty operation of regulators and river tide gates, excessive amounts of storm and river water had to be handled at the treatment plant. This was not economical operation, as the pumping costs increased, the treatment process was upset, and usually gas production took a nose dive, which required the use of electric blowers and fuel oil for boiler heating. In view of these difficulties, operation and maintenance of the sewer regulators and pumping stations were transferred to the sewage plant. A survey of the system revealed the need for considerable rehabilitation work, which when completed resulted in a 10 per cent reduction in power for pumping during the past six months and has aided in restoring gas production and plant purification efficiency to a normal and more regular level. Table I compares summary data for 1951 operation with averages for the preceding 10-year period.

Guard Fence

The original plant construction did not include a guard fence around the three final tanks. As a safety feature, it was quite desirable to put up a fence, but because of World War II, with its shortages of materials, money, and personnel, this was not accomplished until the summer of 1952. A fine job was done by the plant shop crew in erection of the 4-ft. woven wire fence.

Sludge Drying Experiments

The new soil conditioners, such as Krilium, according to the advertisements seem to be the answer to the gardener's prayer. It was thought that, perhaps, the compound would act on digested sludge as it does on clay soil.

To test out the idea, four test sand drying beds were made from halves of 55-gal. drums. Krilium in several concentrations was mixed with the liquid digested sludge and applied to the test beds. In another test it was sprinkled over the surface after three days of normal drying, similar to the application recommended by the manufacturer for soils. Results observed by measuring the filtrate and noticing the sludge condition showed a slight improvement in dewatering, but nothing spectacular. Once again dreams of coming up with a super-duper soil conditioner were shattered.

Digester Cleaning

During September and October, 1952, two digesters were pumped down and cleaned to remove the accumulation of heavy inactive sludge, which, together with scale on the heating coils, was seriously affecting the heat transfer, resulting in poor digestion and low gas production. The pumping was on a 24-hr. basis. When the sludge became heavy it was diluted with raw

TABLE I.—Summary of 1951 and 1941–50 Average Operating Data for the Fort Wayne, Ind., Sewage Treatment Plant

Item	Average 1951	Average 1941-50
Rainfall (in.):		
Recorded	42.64	37.52
Normal	36.18	36.18
Population:		
Served	130,000	130,000
Equiv. (0.17 lb. B.O.D./cap.)	153,667	175,825
Sewage flow:		
M.g.d.	21.40	18.82
Gal. per capita per day	164.5	144.8
Grit removed (cu. ft./m.g.)	2.88	3.03
pH:		
Raw	7.60	7.55
Settled	7.52	7.52
Final	7.44	7.50
Suspended solids:		
Raw (p.p.m.)	217	238
Raw (lb./cap./day)	0.299	0.286
Settled (p.p.m.)	166	179
Final (p.p.m.)	17	16.4
Reduction (%)	92.2	93.1
B.O.D., 5-day:		
Raw (p.p.m.)	150	195
Raw (lb./cap./day)	0.201	0.229
Settled (p.p.m.)	121	154
Final (p.p.m.)	15	15.5
Reduction (%)	89.5	91.8
Activated sludge data:		
Aeration period (hr.)	6.3	7.0
Final settling (hr.)	2.5	2.9
Mixed liq. susp. sol. (p.p.m.)	3,669	2,685
Sludge index	54	89
B.O.D. loading (lb./1,000 cu. ft. cap.)	22.4	28.0
B.O.D. removed (lb./1,000 cu. ft. cap.)	19.6	25.2
B.O.D. removed (lb./1,000 cu. ft. air)	1.23	1.43
Return sl. susp. sol. (%)	1.51	1.18
Return sl. (% by vol.)	28.0	28.5
Air consumption:		
Million cu. ft. per day	13.39	13.86
Cu. ft. per gal. sewage	0.72	0.85
Cu. ft. per lb. B.O.D. rem.	815	702
D.O. after aeration (p.p.m.)	3.4	4.9
D.O. final effl. (p.p.m.)	4.1	4.9
Raw sludge:		
Gal. per day	116,600	108,630
Gal. per m.g. sewage	5,449	5,772
Dry solids (%)	4.4	4.42
Vol. solids (%)	53	60
Supernatant ret. (g.p.d.)	63,600	33,880
Flow ratio (%)	54.5	31.2
Sol. in supernatant (%)	0.1	0.18
Digested sludge:		
Gal. per day	63,200	80,150
Solids (%)	5.4	4.35
Vol. solids (%)	37	43
Dry solids (tons)	4,500	5,049
To drying beds (%)	25	23
To lagoons (%)	75	77

TABLE I.—Summary of 1951 and 1941–50 Average Operating Data for the Fort Wayne, Ind., Sewage Treatment Plant—Continued

Item	1951	Average 1941–50
Gas production:		
Cu. ft. per day	143,950	157,000
Cu. ft. per cap. per day	1.07	1.20
Cu. ft. per m.g. sewage	6,730	8,340
Cu. ft. per lb. vol. sol.	6.6	7.0
Value of gas ($):		
To engine	36,787.00	33,646.00
To boilers	3,091.00	1,492.00
Total	39,878.00	35,138.00
Gas wasted (%)	3.6	7.5
Gas engine operation:		
% of possible time	90.8	92.2
% of air pumped	90.4	87.6
Cu. ft. air per cu. ft. gas	98.3	97.8
Maumee River data:		
Av. flow (m.g.d.)	1,412	1,153
Max. flow (m.g.d.)	9,500	18,850
Min. flow (m.g.d.)	90	42
Upstream ½ mile:		
D.O. (p.p.m.)	9.5	9.1
B.O.D. (p.p.m.)	3.3	3.4
Downstream 5 miles:		
D.O. (p.p.m.)	8.8	8.0
B.O.D. (p.p.m.)	3.6	4.3
Treatment costs ($):		
Labor	99,769.55	73,322.72
Power	31,791.14	30,407.99
Other	19,068.31	17,519.81
Total	150,629.00	121,250.52
Per m.g.	19.30	17.64
Per cap. per year	1.16	0.93
Per 1,000 lb. B.O.D. rem.	19.43	14.10

sewage by back-flushing through the sludge suction line. To complete the operation it was necessary to get into the tanks with a fire hose and gradually slough off and flush the sludge to the suction intake. The ¼-in. thick scale was knocked off the coils and removed from the digesters by means of a portable electric hoist.

The data on one digester are as follows:

Sludge in digester (m.g.)	1.264
Pumped to lagoon (m.g.)	4.980
City water used (m.g.)	1.150
Raw sewage used (m.g.)	2.566
Pumping time (cal. days)	15
Pumping time (actual days)	11
Total time (man-hr.)	245
Scale removed (wheelbarrow loads)	14
Out-of-service time (days)	19

The digesters were put back in service by filling up to the floating cover with raw sewage so as to minimize the possibility of creating an explosive atmosphere. Then they were filled with digested sludge, followed by withdrawal of the supernatant. Raw sludge was added as soon as the temperature reached 90° F. Purging of the gas vents and take-off placed the digester back in full operation. This start-up method insures the smooth take-off of the digestion process. By using it we have never encountered foaming or acid-stage digestion.

Open House

A change of administration in Fort Wayne in 1952 brought with it a number of changes in personnel in the city utilities, mostly in the downtown office. To acquaint the new as well as the old employees with the sewage plant, the

water plant, and the power plant, three "Open Houses" for employees and families were held on three successive Sundays, one at each of the plants. The response was very satisfactory, about 250 people showing up at each plant. With employees acting as guides, they were taken through the plant and served coffee and doughnuts. Everyone, including the management, felt the effort was very much worth while.

OPERATING EXPERIENCES WITH A ROTARY COMMINUTOR *

By J. J. C. Heynike

Ancor Sewage Treatment Works, Springs, South Africa

The satisfactory disposal of raw sewage screenings is a common problem to all sewage works managers. In South Africa screenings removal is generally by hand-operated bar screens. In the larger plants there is a tendency to adopt mechanical bar screens (1) with or without an auxiliary comminuting or macerating pump. The mechanical rake appears to give good service, but where no auxiliary comminuting pump is provided, screenings must still be disposed of by some other method, such as incineration, burying, or perhaps composting. At Pretoria and Cape Town auxiliary pumps for dealing with the screenings are in use, but it appears that this grinding or macerating type of pump also has its shortcomings. At other large plants—the Klipspruit works of Johannesburg, for example—hand-cleaned screens are still preferred.

Conditions are changing rapidly in South Africa and the tendency is to make use of more and more mechanical equipment. With the industrial expansion at Springs, it was decided to use a comminutor for raw sewage screenings disintegration. The unit at the Ancor plant operates at 25 r.p.m. and has a design capacity of 3 m.g.d. (Imp.). The wearing parts responsible for comminuting are as follows:

29 cutting teeth
2 vertical fixed combs
24 vertical cutter bars
1 rubber base seal

All the cutting knives are tipped with tungsten carbide, whereas the fixed combs and vertical cutter bars are tipped with stellite.

Operation

The sewage received at the Ancor works was formerly passed through a hand-cleaned screen with ½- to ¾-in. openings. Under these conditions the average removal of screenings amounted to 24 to 28 cu. ft. per day, or 12 to 14 cu. ft. per m.g. (Imp.).

The comminutor was put in operation on April 6, 1950. The machine was installed ahead of the existing grit chambers, as there was no room available following grit removal. To safeguard the machine from stones and pebbles, a baffle was placed a few feet in front of it in March, 1951. This has been effective.

The flow velocity in the channel just ahead of the baffle appears to be a little too slow, with the result that a large amount of fine grit settles out at this point. This portion of the channel is cleaned every second day, approximately 3 to 4 cu. ft. of fine grit being

* Excerpts from a paper presented at a meeting of the South African Branch, Institute of Sewage Purification; Johannesburg, S. Africa; Sept. 13, 1951.

removed. This is equivalent to about 0.75 cu. ft. per m.g. (Imp.). The volume of grit removed beyond the comminutor is 0.75 to 1.0 cu. ft. per m.g. and contains much less inorganic matter than that removed in front of the machine. Obviously, the greater proportion of the grit present in the sewage does not pass through the comminutor.

The chamber surrounding the base of the machine is drained every morning and coarse material consisting of fine coal, bones, buttons, corncobs, peach pits, etc., is removed. The volume of this material is between one and two double handfuls. About 20 min. are required for the draining and cleaning operation, during which time the sewage is passed through the bar screen.

During the 18 months the comminutor has been in operation it has been necessary to use the hand-cleaned bar screen only while replacement parts were being installed or cleaning of the bowl was required. No major breakdown has been experienced.

Very little attention appears necessary, except that every 2 hr. cotton waste accumulated at the fixed combs is pushed away. The machine cuts just about all kinds of screenings, but increased clearances between the combs and teeth, resulting from wear, allow cotton waste to become entangled, causing overload tripping of the motor switch.

Soon after the comminutor was placed in service it was noticed that some rags, especially the cotton waste used in machineshops and garages, were shredded into long thin strings. In the flow pattern beyond the comminutor these long strings formed "balls," which caused increased blockages of the sludge pumps. A coarse bar screen (4-in. openings) successfully removed these balls, but 8 cu. ft. of screenings were collected daily at this point.

Stringy material hangs on the inside of the comminutor drum. This is removed each day when the comminutor bowl is cleaned and amounts to about 1 cu. ft. per day.

Replacement of Worn Parts

During the first few months of operation it was noticed that some teeth were chipped before becoming worn. Approximately one-third of the teeth were so lost. Replacement of 12 teeth by some of a softer grade of tungsten carbide appears to have remedied this trouble.

Under the conditions at the Ancor works, the life of the various wearing parts appears to be as follows:

Part	Life (days)
Tungsten carbide teeth, two sets	330
Vertical cutter bars, one set	400
Combs[1]	380

[1] Top comb, 446 days; bottom comb, 315 days.

Conversion to a 365-day basis gives the following annual costs of these spares:

Part	Ann. Cost[1]
Teeth	$185.25
Vertical cutter bars	260.06
Combs	131.10
Total	$576.41

[1] At £ = $2.85.

The machine is driven by a 1.5-hp. motor at 380 v. Assuming the load requirements at normal operation to be one-half the rated load, the annual cost for current at ¾ *d.* ($0.0089) per unit is £14 ($39.90). The time required by the mechanic to replace spares is small and is charged at £6 ($17.10) per annum. This brings the total operating costs to $633.41 per year, equivalent to $1.75 per day or $0.70 per m.g. (Imp.).

The original cost of the comminutor was $2,679. For the estimated 15-year life of the machine, amortization and interest at 4 per cent require an annual charge of $241.10. The concrete structure for the machine cost about $712. With a life of 30 years,

and calculated at 4 per cent, interest and amortization amount to about $39.90 per year. Total interest and amortization charge is, therefore, $281.

Formerly, three native laborers with a relief were required on the screen, and another for the raking and burning of screenings, or a total of 4½ continuously for this operation. Now, the one required to remove coarse screenings hourly also sees to the raking and burning of screenings, as well as keeping an eye on the comminutor. The saving in labor alone amounts to about $1,200 annually (at $340 per man per year). The costs given are based on conditions with no baffle in the channel.

Conditions with Baffle

The lives of the various wearing parts as previously given were based on conditions existing prior to installation of the baffle in front of the comminutor. Although no measurement of grit removed in the upstream channel was made before the baffle was used, there is reason to believe that the volume of grit then removed was less than is found now (0.75 cu. ft. per m.g.).

Since the last new set of teeth was put in on March 7, 1951—that is, 12 teeth of a softer grade and 17 of the normal grade tungsten carbide—only 3 of the normal grade have been lost. Consequently, the present teeth have been in service 190 days and, on examination, should give a life of 250 days, or a 57 per cent improvement. The first sets lasted 165 days each. A proportionately longer life also is indicated for the combs and cutter bars. At 50 per cent improvement, the cost for spares will be about $285, bringing the total annual operating costs to about $342, or $0.38 per m.g. These cost data indicate the large saving that results from removal of most of the grit.

By comparison, cost per m.g. for parts only at Marion, Ind., was given by Backmeyer (2) as $0.27, with grit removal effected after the sewage has passed through the comminutor. Also, the screenings at Springs, amounting to 12 to 14 cu. ft. per m.g., are much greater than the U. S. average of approximately 2 cu. ft. per m.g. Furthermore, the Springs screenings are unusual in the amount of cotton waste contained.

Conclusions

1. The volume of screenings in the sewage at Springs, S. Africa, is at least 5 times that found in sewage in the United States.

2. The comminutor can cope with all types of screenings except the cotton waste used in machine shops and garages.

3. The bigger portion of this cotton waste appears to be clean and probably comes from latrine houses.

4. The presence of the cotton waste can be largely ascribed to its indiscriminate use by the large native population at Springs (ratio of Europeans to natives = 1:3).

5. Removal of the cotton waste would greatly reduce the cost of comminution.

6. The cost of replacing worn parts can be reduced by sharpening the teeth before they are worn too far. A further saving may be realized by having the teeth retipped with tungsten carbide locally.

7. Installation of a coarse screen ahead of the comminutor might improve comminutor operation by removing the cotton waste.

References

1. Loewenstein, P. R., "The Works Manager Chats." *Pub. Health* (S. Af.), **15**, 9, 207 (1951).
2. Backmeyer, D. P., "Pretreatment Devices at Marion and Richmond, Indiana—Comminutors." THIS JOURNAL, **22**, 7, 949 (July, 1950).

TIPS AND QUIPS

Safety Check List

Periodic check-up on safety measures and the condition of safety equipment is a necessity if one is to be sure that everything is functioning as it should or is in readiness for instant use in case of emergency. A good place to start is in your own plant, with the following check list, published in the February, 1953, issue of *The Overflow*, news letter of the Florida Water and Sewage Works Operators Association:

1. Gas masks—condition of rubber, straps, and canisters.
2. Canisters—chlorine, ammonia, all-purpose.
3. First aid kits—enough for each vehicle and each emergency station.
4. First aid refills.
5. Burn ointment—for burns, insect bites, and skin irritations.
6. Safe work clothing—rubber suits, raincoats, hats, rubber boots, steel-toed boots and shoes, and goggles or face guards.
7. Work gloves and aprons—leather gloves, rubber gloves, chemical aprons.
8. Ladders—extension and step ladders, wood ladders, metal ladders, broken rungs and steps, condition of ends, non-slip devices, ropes, pulleys, catches.
9. Stretchers—fabric, side rails, fastenings, availability.
10. Respirators and resuscitators—lime and chemical dust respirators, equipment for artificial resuscitation.
11. Rope—handline and cables.
12. Tools and machines—are tools safe, machines guarded?
13. Floors and walkways—are they slippery or clean?
14. Rails and guards—is there a pit to fall in?
15. High voltage—is it marked by a danger sign or guard fence?
16. Safety meetings—are they held and how often?
17. Cars and trucks—broken lights, tires, safe seats for transporting men to and on job.
18. Barricades and signal lights—use on street openings, number, condition.
19. Do all the men practice safety?—for their own sakes, for their families' sakes, and for the sake of others' safety?

Sludge Drawing Hints

If sludge is to be drawn from a clarifier into a concrete transfer box or sludge vault preparatory to pumping, and sludge flow is dependent on the differential head between the tank and the outlet level, starting and maintaining the flow at the desired rate often presents a problem. To overcome the difficulties, the Boise, Idaho, plant publication *Sewage Gas* offers two suggestions, as follows:

1. If the settled sludge becomes heavy and will not start flowing, and compressed air is available, tap the sludge line from the clarifier as close to the sludge hopper as possible and pipe the air to this point. Very little air is required to start the sludge moving.

2. To control the volume of flow, many drawoff arrangements are possible. Good success has been had with a swing-type valve, which, by means of a chain and pulley, can be set easily at any desired elevation with a minimum of time and effort. The valve is made by using two 6-in. elbows, a close 6-in. nipple, and short pieces of 6-in. pipe. The hydraulic head is changed quickly and easily to start the flow. Then the swing pipe may be set to draw sludge at any rate desired by simply raising or lowering the swing pipe.

Starting Off on Right Foot

Good operation most often leans heavily on complete and accurate rec-

ords, from which also come the information and data needed for good annual reports. It is gratifying, therefore, to find the supervisor of a new plant building the firm basis for future operating success with his plant, as exemplified by the recently received "First Annual Report" of the Washington, Ind., sewage treatment plant, extracted elsewhere in this "Corner." Congratulations to Superintendent Jesse A. Behle for taking the important first step in the right direction!

Do's and Don'ts for Wire Rope and Fittings

1. Inspect, clean, and lubricate all wire rope regularly. Tighten all fittings. Be sure the hemp core is not dry, otherwise corrosion, abrasion, or fatigue will occur.

2. Be sure the rope is the proper one for the service. It should have the proper strength, flexibility, and resistance to abrasion, fatigue, crushing, and heat.

3. If drums or sheaves are small or the kinking tendency is pronounced, consider pre-formed rope.

4. Be sure the rope fits the sheaves or drum grooves. Too large a rope or worn grooves cause pinching and rapid wear.

5. Sheaves and drums that are too small in diameter cause rope fatigue.

6. If the rope deviates from the center plane of the sheave more than 1½°, undue wear will result.

7. Keep sheaves aligned, and bearings tight and properly lubricated.

8. Prevent rope slippage on the sheaves.

Tree-Root Garden

Tree-root penetration of joints in all common types of soil pipe material is the primary study objective of an unusual tree-root garden at the University of Alabama. Sponsored by the Cast Iron Soil Pipe Institute, the garden reproduces test conditions similar to those found outside homes across the entire country. Although a recent report presents the first year's findings, the project obviously will need more time before significant results appear.

New Digester Problem?

Low gas production in the digester of the Urbana-Champaign (Ill.) Sanitary District sewage treatment plant during January brought with it not only heating problems, but also some fanciful suggestions as to causes and remedies. Gas production, normally in the range of 20,000 to 25,000 cu. ft. per day, dropped to an astonishing low of 800 cu. ft. on one day and around 4,000 cu. ft. on a number of other days. Furthermore, it was low in B.t.u.'s. One expert theory, that there might be an excess of copper in the sewage, was quickly disproved by chemical tests.

A reporter for one local newspaper came up with a more "scientific" explanation—at least it had some basis in what he considered "fact." According to his article, "The only other theory seems to lie in the disturbed state of the health of a large portion of the community and the consumption of vast quantities of antibiotic drugs, penicillin, aureomycin, etc., in which the pharmacies did a land office business."

Whatever the cause, the "deep freeze," as it was called by another local newspaper, continued, with District employees wearing their overcoats at work and bringing electric heaters from home. By the middle of February gas production was approaching normal, but for a time, according to E. J. Beatty, District engineer-manager, "it was so cold my dog refused to sit on the floor—he wanted a chair!"

Reviews and Abstracts*

High-Rate Digestion of Strong Organic Wastes (Strawboard Paper Wastes). By H. Jung. *Vom Wasser*, **17**, 38 (1949).

In laboratory batch experiments the bacterial floc is kept in suspension in the digester by continual stirring. For effective reduction of $KMnO_4$ O.D., 30 per cent settled ripe solids seed is necessary. With 50 per cent seed, a 60 per cent reduction in $KMnO_4$ O.D. was obtained. Control experiments with activated sludge showed approximately the same degree of purification. On a pilot-plant scale, retention time in the rapid digester was 15 hr. The effluent was settled from 1 to 2 hr. From the sedimentation unit, sludge was pumped back to the rapid digester and to a regenerating digester. From the latter, ripe solids were pumped to the rapid digester at a rate resulting in a complete turnover once a week. Volatile solids, B.O.D., and $KMnO_4$ O.D. reductions were 41, 40, and 50 per cent, respectively. The method is considered suitable as pretreatment for strong organic industrial wastes.

Peter K. Mueller

An Improved Settling Tank Design. By H. A. Thomas and J. L. Dallas. *Jour. Boston Soc. Civil Eng.*, **39**, 4, 354 (Oct., 1952).

Logic and theory are presented to show that settling tanks may be designed smaller in volume and yet should give results equal to those of conventional tanks with the same surface area. A study of the paths of settling particles shows that much of the upper volume of the ordinary tank is not used other than to keep the velocity low. By sloping the bottom up toward the outlet, using multiple outlet troughs spaced, say, at quarter points, and putting the inlet deep, it is shown that all of the volume can be used and lower detentions realized.

Models of a conventional tank and a sloping bottom one with 75 per cent the capacity of the former, were tested. The results, which are tabulated at several rates of flow, showed practically equal B.O.D. and suspended solids removal.

Wm. A. Hasfurther

Modified Deinking Sludge May Find Several Markets. Anon. *Chem. Eng. News*, **30**, 3543 (1952).

The Kalamazoo River Improvement Co. has announced that its laboratory at Western Michigan College in its first annual report finds that utilization of sludge discharged from de-inking mills is possible both technically and economically.

R. S. Ingols

Calculation of Storage in Surface-Water Sewerage. By L. B. Escritt. *Surveyor*, **111**, 679 (Oct. 24, 1952).

This article is a sequel to another which appeared in an earlier issue of *The Surveyor* (**111**, 627). The more recent article contains a fuller mathematical treatment of the considerations involved in this type of calculation, and in addition treats the effect on the required capacity of wet wells.

M. C. Rand

National Water Resources Policy Recommendations. By Samuel B. Morris. *Jour. Amer. Water Works Assn.*, **44** 4, 287 (1952).

The author gives the philosophy upon which proposed legislation by the President's Water Resources Policy Commission was based. This proposed legislation was made public on Feb. 18, 1952, and the appendix to Mr. Morris' statement gives

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns., 325 Illinois Bldg., Champaign, Ill.

excerpts from the Proposed Water Resources Act of 1951. Essentially it calls for the organization of river basins with committees of both state and federal members, as recommended in the three-volume report of the Commission. In spite of much recent criticism of the report's suggestion of federal participation, the need for such cooperation in these large interstate projects is emphasized.

ROBERT P. LOWE

Use of Membrane Filters in Water Analysis. BY C. R. BAIER. *Vom Wasser*, **17**, 93 (1949).

Membrane filters were used to differentiate between the following suspended solids in water:

1. Total suspended solids.
2. Suspended solids not retained by filter paper (Schleicher and Schull 589.2).
3. Acid insoluble suspended solids (for example, sand, clay, fibers, plankton, and organic detritus).
4. Acid soluble suspended solids, especially ferric hydroxide.

To obtain (3) the residue in (1) was treated with 10 per cent HCl. (4) was obtained by treating filtrate from (3) with ammonium hydroxide to precipitate the ferric hydroxide. The determination of iron was simplified by concentration on membrane filters. More accurate separation of colloidal from truly soluble iron has been made possible. The appearance of membrane filters after filtration shows the effect of aeration and chlorination of iron- and manganese-containing waters.

PETER K. MUELLER

Udem Sewage Treatment Plant. BY F. SCHMITZ-LENDERS. *Ges.-Ing.*, **73**, 333 (1952).

A trickling filter plant of 6,000 people design capacity handles the wastes of 4,500 people and a dairy discharging 19,000 g.p.d. Total dry-weather flow is 4.22 gal. per sec. The plant is capable of handling 12.7 gal. per sec. Larger quantities of storm water are stored in a lagoon until lower flows permit release to the plant. Primary settling and digestion proceeds in a two-story tank. The upper, or settling, chamber has a 42-ft. diameter and 5,120-cu. ft. capacity. The sludge is mechanically scraped through an orifice to the lower, tapered, digestion chamber of 7,940-cu. ft. capacity. Building costs were calculated to be 10 per cent less than those for a comparable Emscher tank. Floating scum problems have not been encountered. PETER K. MUELLER

Sewage and Industrial Waste Treatment in Switzerland. BY WALTER DARDEL. *Jour. and Proc. Inst. Sew. Purif.*, Part 3, 174 (1950).

The paper is a review of sewage and industrial waste treatment in Switzerland, a country blessed with fine lakes, waters, and climate, which factor has retarded the need for liquid wastes treatment until the present.

Legislation to prevent water pollution was enacted in 1888, but was inadequate and was later amended in 1925. The amended law, however, provided no way of forcing a municipality to construct waste treatment works unless it elected to do so. A new law now proposed more clearly defines pollution and responsibility and provides for punishment of offenders. It is a revision of the constitution of Switzerland. The proposed control is opposed by industry.

Because of local waste disposal to lakes, many Swiss scientists have devoted great effort to limnology. Summer and winter profiles are given for Lake Zurich.

In 1936, a Federal Institute of Sewage Purification was established to study sewage and waste treatment in Switzerland. It is to be noted that sanitary engineers cannot get formal training within the country and consulting engineers from foreign contries often did poorly when designing waste disposal plants for Swiss cities because of lack of experience in these areas. This institute initiated sewage research in Switzerland by building a flexible pilot plant. In 1944 the Swiss Association of Sewage Professionals was created to study sewage treatment.

Sewers are usually designed as combined and of course maximum rainfall intensity enters the problem. Maximum rain intensity was given at 5.4 in. per hr. Dry-weather sewage flow varies from community to community, values given being 44 to 110 g.p.c.d. Sewage characteristics are similar to U. S. sewage.

The sewage plants of St. Gall, Zurich, and Winterthur are described.

Also described is a process known as "ferrisation." This is essentially the production of ferric hydroxide floc by violently mixing air and water with a deposit of iron filings in a special mixing tank, thus producing a flocculation agent at a cost lower than could be done using ferric sulfate. The method is used in sewage and industrial waste treatment with considerable success.

An accelerated biological process of secondary sewage treatment, entitled the Z-process, is of considerable interest. It is a process whereby 1 lb. of asbestos fiber is inserted in the aeration tank influent for each 17.5 cu. ft. contents of aeration tank. Settled sewage is aerated in the usual manner for 1 hr., followed by 1½ hr. of settling. The final tank sludge, containing the inert asbestos fiber, is continuously returned to the aeration tank influent. The process showed 73 per cent B.O.D. removal for an extremely weak sewage.

Description of a waste acid liquor treatment plant using dolomite and lime powder for neutralization is given; also two waste disposal plants are described which handle liquid wastes from chemical product factories. One chemical factory produces chlorine, carbonate of soda, colors, etc.; the other produces oils for the varnish industry, dried oils, artificial oils, synthetic resins, and cellulose derivatives.

A small plant treating wastes from a tannery using the vegetable-tan process is described as removing 99 per cent of the suspended solids and 50 per cent of the oxygen demand as measured by the $KMnO_4$ test. Waste waters from metal plating and sugar beet plants are treated in plants described briefly.

K. W. Cosens

Removal of Radioactive Waste from Water. By Conrad P. Straub. *Nucleonics*, **10**, 1, 40 (1952).

A description is given of the experimental water treatment plant designed and built at Oak Ridge National Laboratory to study the removal of radioactive materials by conventional water treatment processes. The pilot plant has a capacity of 250 g.p.d. and consists of two mixing basins in parallel, a flocculation tank, a settling basin, a flow proportioning and sampling tank, and a constant head tank for feeding the 10 lucite filter columns.

The treatment methods discussed briefly include evaporation, carrier precipitation, ion exchange (synthetic resins and natural clays), biological processes, metallic displacement or scrubbing, sand filtration, crystallization, and other processes. Where results are available from studies of these treatment processes these have been reported.

Conrad P. Straub

Some Factors Affecting the Viablility of Faecal Bacteria in Water. By L. A. Allen, S. M. Pasley, and M. Pierce. *Jour. Gen. Microbiol.* (Gt. Brit.), **7**, 36 (1952).

The effect of various conditions on the rate of death of *Bacterium coli* and of *Streptococcus faecalis* in dilute buffer solutions was followed by making colony counts at intervals during prolonged periods of incubation and then constructing mortality curves. The form of these curves was characteristic for each organism. Of the pH values investigated (approximately 5, 6, 7, and 8) both organisms were least viable in the range 6 to 7. *S. faecalis* was not affected by the degree of oxygenation of the water, but *B. coli* died much more rapidly under anaerobic than under aerobic conditions.

Growth of *B. coli* was observed with as little as 0.28 p.p.m. organic matter in solution. A much higher concentration of nutriment was required for growth of *S. faecalis;* with a concentration slightly below that required for growth the viable population remained virtually stable for a long period. The rate of death depended on the age of the cells at the time of immersion in water. H. P. Orland

Attempts to Improve the Delta Works Effluent in Order to Avoid Stream Pollution. By E. G. White. *Pub. Health* (S. Africa), **16**, 9, 198 (1952).

The Delta works at Johannesburg, Union of South Africa, built as an activated sludge plant, had been enlarged, first by increasing the depths of the tanks and adding a sludge reconditioning unit and later by adding two biological filters, humus tanks, and sand filters. Recently, while preparing to divert part of the flow to another plant, temporary measures described in this paper were taken to prevent complaints.

Activated sludge settled poorly, gas bubbles rising to the surface and oxygen and nitrates decreasing. Air or oxygen blown into the liquor before settling eliminated these conditions but proved costly and was not used long.

Trickling filter effluent was too poor to treat satisfactorily on the sand filters. To improve both sections of the plant the load to the activated sludge units was decreased until a highly nitrified effluent resulted. A portion of this, after settling, was then mixed with sewage going to the trickling filters. The humus tank effluent then showed a reduced oxygen absorption, an increased relative stability, nitrites regularly, and nitrates occasionally.

Now, although the Delta plant loading has been reduced, about one-half the activated sludge effluent still goes to the filters and a settled effluent with 15 to 20 p.p.m. nitrates and 14.2 p.p.m. average 4-hr. oxygen absorbed results. Loading data are meager, but computations from a few figures show the mixed wastes to the trickling filter had a 4-hr. oxygen absorbed value of 40 p.p.m.

WM. A. HASFURTHER

Acid Mine Drainage Problems—Anthracite Region of Pennsylvania. BY S. H. ASH, E. W. FELEGY, D. O. KENNEDY, AND P. S. MILLER. Bull. 508, Bur. of Mines, U. S. Dept. of Interior. (Supt. of Doc., U. S. Gov't. Printing Off., Washington 25, D. C.) 72 pp. Price, $0.60 (1951).

The major drainage problem of the anthracite region of Pennsylvania concerns satisfactory disposal of the mine-water discharge averaging 474 m.g.d. and containing a free-acid load of 431 tons or a total acid load of 934 tons per day as H_2SO_4. The report indicates the scope of the problem and gives some suggestions concerning its solution.

Diversion of individual mine drainage in the anthracite region from receiving streams and purification of mine drainage before entering streams are alternative remedial measures to combat pollution of surface streams by acid mine drainage. The approximately 327,000 g.p.m. drainage from the mines of the anthracite region represents a not inconsiderable quantity of water, and the effect of its removal from the surface streams is a phase that must be considered. When collected and made available at one point, it also is a potentially valuable source of water supply for industrial or other use if its chemical quality can be made suitable. H. P. ORLAND

Aquatic Invertebrates as Indicators of Stream Pollution. BY A. R. GAUFIN AND C. M. TARZWELL. *Pub. Health Rep.*, 67, 1, 57 (1952).

Year-round field studies of the biology of stream sanitation, carried on at Lytle Creek by the biology section of the U.S.P.H.S. Environmental Health Center at Cincinnati, Ohio, led to the following conclusions:

1. Single species of organisms such as *Tubifex tubifex* or *Chironomus tentans* cannot be used safely as indicators of pollution unless their relative abundance is considered.

2. The absence or much reduced numbers of formerly present clean-water species constitutes an important index in evaluating the degree of pollution.

3. The quantitative and qualitative composition of an aquatic population constitutes a valuable index in delineating zones of pollution in a stream.

4. In interpreting the distribution of organisms in a stream as an index of pollutional conditions, all environmental factors should be considered.

5. Pollutional associations are characterized by few species but large numbers of individuals.

6. The association of organisms normally present under most septic conditions is characterized by the absence of plant and animal eaters and the presence of scavengers.

7. Organisms characteristic of septic zones are those which can exist under conditions of very low oxygen or have adaptations for breathing atmospheric oxygen.

8. Nocturnal deficiencies in dissolved oxygen are often the critical environmental factor which determines the distribution of organisms in a stream.

9. Under conditions of organic pollution diurnal-nocturnal deficiencies in oxygen are sometimes concomitant with supersaturation of dissolved oxygen.

H. P. ORLAND

B.O.D. Determination of Sewage by the Direct Method Using a Warburg Apparatus. By K. Jaeger and W. Niemitz, *Stadtehygiene*, No. 9 (1952).

Spherical, 125-c.c. flasks are employed. Using nine samples ranging from 17 to 243 p.p.m. 24-hr. Warburg B.O.D., the mean deviation was 4.2 per cent and the maximum deviation was 7.3 per cent. Using 6 samples with B.O.D.'s of more than 50 p.p.m. the mean deviation was 2.8 per cent and maximum deviation 4.7 per cent. Therefore, the reproducibility of the direct method is better than that of the dilution method. For routine analyses 24-hr. Warburg B.O.D.'s, and for more accurate work 48-hr. B.O.D.'s, are recommended. Temperature should be 25° C. Sample volumes from 5 to 40 c.c. do not influence results significantly. Oxygen slightly lowers B.O.D. of raw sewage, but has no effect on B.O.D. of trickling filter effluent.

Comparison of direct with dilution method showed that 24-hr. Warburg B.O.D. of raw sewage was 74 and 53 per cent of the 5-day B.O.D. using tap and seeded distilled dilution water, respectively. The values for trickling filter effluents were 59 and 38 per cent, respectively. The lower values for the effluent indicate the effect of nitrification. Therefore, the direct method would yield values more representative of the carbonaceous B.O.D.

Other advantages of the direct method are the ability to continuously observe metabolic processes in a single experiment and the curtailing of testing time of control analyses to a day or less. This would not be possible with the dilution method under any circumstances. B.O.D. reductions of a trickling filter plant were 93, 90, and 94 per cent as measured by 24-hr. Warburg, and dilution method using tap water and seeded distilled water, respectively. Application of the direct method to industrial wastes is described. The direct method has been applied to correlate pH, redox potential, and nitrification stages with breakdown processes.

Peter K. Mueller

Determination of the B.O.D. of Sewage and Industrial Wastes with the Polarograph. By A. W. Busch and C. N. Sawyer. *Anal. Chem.*, **24**, 1887 (1952).

The polarographic method for determining the initial and final dissolved oxygen values in B.O.D. determinations is possible. The single-potential technique is used. The precision and accuracy is good, with less time required for each D. O. analysis for the polarograph technique than for the Winkler method with the required modifications where industrial wastes are involved. R. S. Ingols

Investigations into a New Method of Effluent Liquor Purification. By C. Cooper and W. E. Bouch. Publ. No. 399, Inst. of Gas Eng. (Gt. Brit.) (1951).

Nitric and nitrous acids were investigated as possible agents for the destruction of the residual toxic matter in ammonia still effluents and other effluents from gas works. The effect of the reactions is to destroy the inorganic salts, such as thiosulfate and thiocyanate, the products of decomposition of nitric acid being largely recoverable for further use after oxidation with air. The total effect is to convert the toxic salts to comparatively harmless substances by indirect use of atmospheric oxygen.

Phenolic contaminants combine with nitric acid, which is thereafter unrecoverable.

Nitric acid or nitrogen oxides for these purposes can be obtained by the catalytic conversion of ammonia.

Chlorides affect the reactions, assisting decomposition of other ammonia salts, but continuing to react with nitric acid. Nitrated phenols in the treated solutions may require removal. Where fairly high concentrations of thiocyanate are available, it may be possible to recover hydrocyanic acid at a profit. H. P. Orland

Conditions Affecting the Growth of *Bacterium coli* on Bile Salts Media. Enumeration of This Organism in Polluted Waters. By L. A. Allen, S. M. Pasley, and M. Pierce. *Jour. Gen. Microbiol.* (Gt. Brit.), **7**, 257 (1952).

The growth of *Bacterium coli* on agar media containing bile salts is conditioned by a number of factors. The proportion of total cells able to grow on a medium not containing bile salts rapidly declines at temperatures of incubation above 43° C. On a medium containing bile

salts and lactose a distinctly inhibitory effect is observed at 37° C.; with most strains this effect is still more pronounced at 44°. Some brands of bile salts are appreciably more inhibitory than others. Inclusion of phosphate in a bile salts medium introduces a markedly inhibitory factor, the severity of which varies with the strain of organism; some strains are virtually unable to grow on such a medium.

When a culture of *B. coli* is suspended in water containing only small concentrations of inorganic salts, an increasing proportion of the population becomes attenuated so that the cells are unable to grow on bile salts lactose agar at 44°. An occasional strain may also exhibit sensitiveness to the presence of neutral red. This attenuating effect may be largely decreased if, before the inoculum is mixed with the bile salts and agar, it is subjected to a short period of incubation with lactose broth. This treatment has been made the basis of a technique for obtaining a colony count of *B. coli* which is applicable to polluted waters.

H. P. ORLAND

Report on the Investigation of Leaching of Ash Dumps. Publ. No. 2, State Water Poll. Control Board, Sacramento, Calif. Price, $1.00 (1952).

This investigation was made by R. C. Merz and J. R. Snead of the Sanitary Engineering Research Laboratory, University of Southern California. The conclusions reached are as follows:

1. Percolation of natural precipitation or movement of ground-water through an incinerator ash dump will leach soluble salts and alkalies from the dump.

2. The rate of leaching will be very slow, even when water volumes far in excess of those derived from maximum precipitation or normal ground-water flow are applied to the ash surface.

3. The maximum amount of any cation that may be reasonably expected to be leached from an incinerator ash dump over a period of at least 5 years will be 2.9 lb. per cubic yard (sodium). This value will decline considerably over subsequent 5-year periods.

4. The maximum amount of any anion that reasonably may be expected to be leached from an incinerator ash dump over a period of at least 5 years will be 5.3 lb. per cubic yard (chloride). The chloride content of the ash will very likely be exhausted within that time. There will be a simultaneous leaching of 5.0 lb. of sulfate per cubic yard, but this value, too, will decline considerably over subsequent 5-year periods.

5. Chlorides and nitrates will be rapidly and completely removed by leaching. Sulfates will be leached at a slightly lower rate. Calcium and magnesium will be leached very slowly, whereas the rate for sodium and potassium will be the fastest of the cations. It is unlikely that all the cations would ever be removed.

6. The annual precipitation in the Southern California area will penetrate an ash dump approximately 6 ft. Subsequent years may be expected to produce equal increments of penetration, assuming normal precipitation.

7. The average rate of penetration through a uniform ash during a period of greatest rainfall will be in the magnitude of 0.20 ft. per day.

8. A typical incinerator ash may be expected to exhibit ion exchange properties, and to have exchange capacities approaching one-tenth to one-twentieth that of commercial cation exchangers, and one-half that of glauconite. H. P. ORLAND

Determination of Residual Chlorine in Metal Finishing Wastes. By H. C. MARKS AND N. S. CHAMBERLAIN. *Anal. Chem.*, **24**, 1885 (1952).

In the treatment of cyanides, residuals with high ratios of combined to "free" chlorine are produced. The "free" chlorine cannot be determined with the O.T.A. test, but a modified amperometric instrument can be used. Chromates liberate color from ortho-tolidine to behave like chlorine, but the amperometric titrator can be used in the presence of chromates without interference. The amperometric titration for chlorine is satisfactory with cadmium, nickel, zinc, and chromic ion up to 1,000 p.p.m. The cuprous ion, silver, and to a less extend the cupric ion, interfere in the amperometric titration.

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Proceedings of Member Associations

KENTUCKY–TENNESSEE INDUSTRIAL WASTES AND SEWAGE WORKS ASSOCIATION

The 6th Annual Meeting of the Kentucky-Tennessee Industrial Wastes and Sewage Works Association was held jointly with the Kentucky-Tennessee Section, AWWA, at the Andrew Jackson Hotel, Knoxville, Tenn., on September 15–17, 1952. Registration for the meeting totaled 255.

Officers elected for 1952–53 were as follows:

Chairman: H. D. Regan, Lexington, Ky.

Vice-Chairman: K. B. Stallings, Nashville, Tenn.

FSIWA Director: F. W. Kittrell, Oak Ridge, Tenn.

Secretary-Treasurer: R. P. Farrell, Nashville, Tenn.

R. P. Farrell,
Secretary-Treasurer

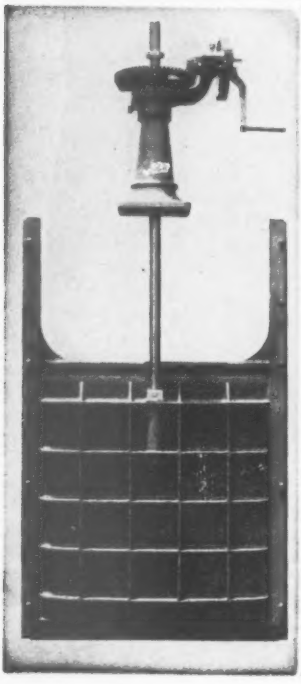
NEBRASKA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The First Annual Meeting of the Nebraska Sewage and Industrial Wastes Association was held at the Clarke Hotel, Hastings, Nebr., on November 13–14, 1952. Registration for the meeting totaled 24.

Papers presented included the following:

"Operation of Mechanical Aeration Plants," by John A. Voegtle, Sanitary Engineer, Chicago Pump Co.

(*Continued on page 192a*)



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"Stream Pollution Legislation—Panel Discussion," by John Cramer, Consulting Engineer, Lincoln; T. Filipi, State Dept. of Health, Lincoln; and D. R. Hill, Superintendent, Sewage Works, Hastings.

"Sewage Treatment Plant Design as Related to Good Operating Facilities," by W. H. Wisely, Executive Secretary, FSIWA.

"Operators' Breakfast and Question Box," by a panel consisting of R. Babcock, Portland Cement Assn., N. Platte; Scott Wilber, Superintendent, Sewage Treatment Plant, Omaha; and J. M. Orrell, Operator, Sewage Treatment Plant, Imperial.

A social hour, courtesy of the Water and Sewage Works Manufacturers' Association, preceded the banquet on November 13. At the banquet, the featured speaker was W. H. Wisely, Executive Secretary, FSIWA, whose topic was "Public Relations from the Standpoint of the Sewage Plant Operator."

Officers elected to serve during 1952–53 were:

President: M. S. Fitzsimmons, Lincoln.
Vice-President: C. Welton, Sidney.
FSIWA Director: Scott Wilber, Omaha.
Secretary-Treasurer: P. W. Mousel, McCook.

The meeting closed with an inspection trip to the Grand Island sewage treatment plant.

PAUL W. MOUSEL,
Secretary-Treasurer

FLORIDA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 1952 Annual Meeting of the Florida Sewage and Industrial Wastes Association was held jointly with the Florida and Alabama-Mississippi Sections, AWWA, at the San Carlos Hotel, Pensacola, Fla., November 16–19, 1952. Registration of members and guests totaled 294.

Papers presented included:

"Historic Controversies in Sanitary Engineering," by E. Sherman Chase, President, FSIWA.

"Significance of Biological Analysis to Stream Pollution Studies," by James B. Lackey, Professor of Sanitary Science, University of Florida.

"Design and Construction Features of the Panama City Water and Sewerage Improvement Program," by A. J. Birchall, Smith and Gillespie, Engineers, Jacksonville.

"The Palm Beaches Sanitary District," by W. W. Gillespie, Smith and Gillespie, Engineers, Jacksonville.

"Plating Plant Waste and Its Effect on Sewage Treatment at Naval Air Station, Pensacola, Fla.," by S. C. Hastings and R. S. Blondheim, Mechanical Engineer and Chemical Engineer, respectively, Base Public Works Division, N. A. S., Pensacola.

"Garbage Disposal by Bacterial Digestion," by C. H. Carothers, Carothers Laboratory, Miami.

"Gadgets for Sewage Treatment Plant Operation," by G. T. Lohmeyer, Superintendent, Sewage Treatment Plant, University of Florida, Gainesville.

"Design Problems of Sanitary Sewage Facilities for Real Estate Subdivisions," by W. J. Parks, Reynolds, Smith and Hills, Engineers and Architect, Jacksonville.

Inspection trips were made to the Pensacola water plants and to the St. Regis paper mill. Social events included a fish fry at the Pensacola Yacht Club. A Club Room was sponsored by the Water and Sewage Works Manufacturers Association representatives present.

Officers elected for 1952–3 were:

President: J. W. Wakefield, Jacksonville.
Vice-President: W. C. Tims, Tampa.
Secretary-Treasurer: D. P. Schiesswohl, Jacksonville.

DONALD P. SCHIESSWOHL,
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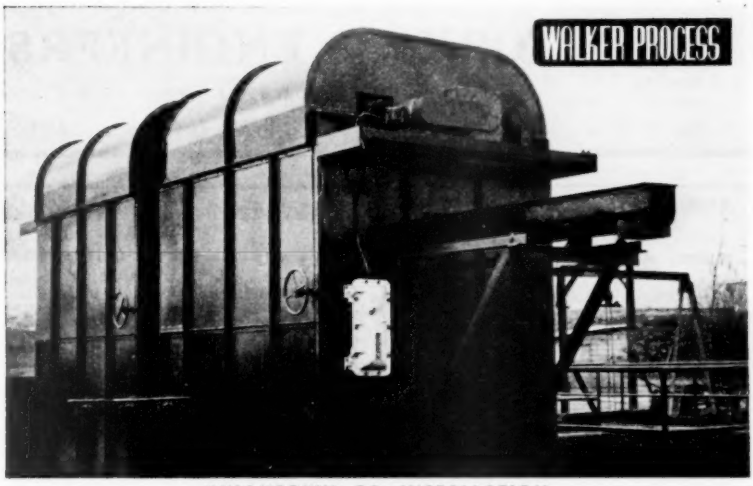

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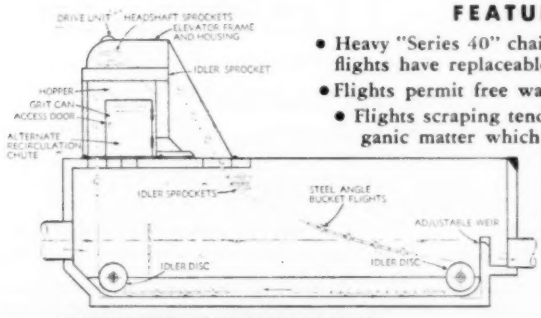

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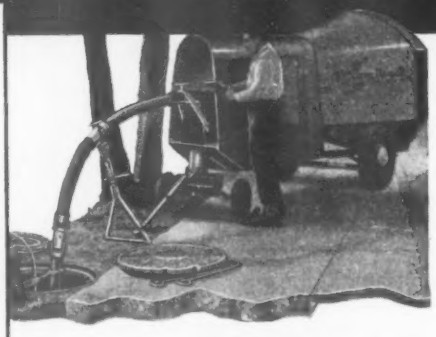

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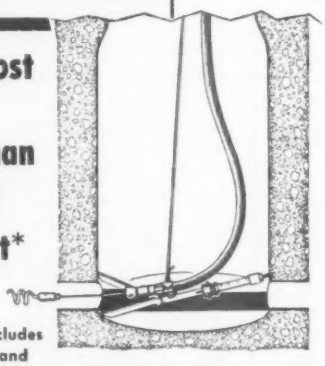

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